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Comparative Tests of Permeability of Five Cement Mortars

Specimens Made with Special Cement, With Waterproofing Cement, and With Standard Portland Cement With and Without Admixtures—Test Procedure and Apparatus

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TESTS have been conducted by the James H. Herron Company laboratories to determine the relative values of Super Cement in comparison with ordinary portland cement, waterproofing cement, and portland cement containing admixtures, for strength and permeability.

These tests were made on Super Cement and ordinary portland cement, in comparison, with the following schedule:

1. A. S. T. M. standard tests for cement, with extra briquettes for 90-day tests.
2. A. S. T. M. standard tests on mortar cylinders (2-in. dia. by 4 in. high) with Ottawa sand, at 7, 28 and 90 days.
3. Complete tests on fine and coarse aggregate to be used in the concrete.
4. Mortar tests on the fine aggregate used in the concrete for tension and compression at ages of 7, 28 and 90 days.
5. Concrete cylinders for compression tests (6 in. dia. by 12 in. high) for ages of 7, 28 and 90 days.
6. Permeability tests on 6- by 6- by 1-in. mortar specimens, at ages of 7, 28 and 90 days, covering the following combinations:
    (a) Super Cement.
    (b) Ordinary portland cement.
    (c) Ordinary portland cement with diatomaceous earth.
    (d) Ordinary portland cement with hydrated lime.
    (e) Waterproofing cement.

All materials were sampled by a representative of the James H. Herron Company, purchased from fresh stock in the open market.

Methods of Tests

For the cement, sand, stone and concrete cylinder tests, the standard tests of the American Society for Testing Materials were used.

The permeability tests, with which this article is mainly concerned, were made on mortar specimens 6- by 6- by 1-in. in thickness, and were tested under a working pressure of 30 lb. of water pressure per sq. in. for one hour, and the effects noted.

Mortar composed of one part of cement to 2 parts of concrete sand (tests given in Table 1) was used for all of the specimens in the permeability tests. Nine specimens 6 by 6 by 1 in. in size were made for each of the following different materials:

(a) Super Cement;
(b) Portland cement;
(c) Portland cement and 5 per cent diatomaceous earth, by weight of the cement;
(d) Portland cement and 5 per cent hydrated lime by weight of the cement;
(e) Waterproofing cement.

TABLE 1—RESULTS OF TESTS OF SAND AND MORTAR

Concrete Sand Tests

Weight per cu. ft. (rodded), lb.	109.0
Specific gravity (apparent)	2.57
Voids (rodded), per cent	32.7
Silt (by decantation), per cent	2.2
Organic impurities	Satisfactory, clear

Sieve Analysis of Sand

Per cent retained on No. 100 sieve	96.0
Per cent retained on No. 50 sieve	86.0
Per cent retained on No. 30 sieve	57.9
Per cent retained on No. 16 sieve	34.2
Per cent retained on No. 8 sieve	18.4
Per cent retained on No. 4 sieve	5.5
Per cent retained on ⅜-in. sieve	0.0
Fineness modulus	2.98

Tensile Strength, 1:3 *Concrete Sand Mortars*

	Portland Cement Mortar			Super Cement Mortar		
	7 Days	28 Days	90 Days	7 Days	28 Days	90 Days
	270	365	500	270	385	560
	260	385	520	280	395	570
	275	385	515	270	405	520
Av.	268	378	512	273	395	550

Compressive Strength, 1:3 *Concrete Sand Mortars*

	Portland Cement Mortar			Super Cement Mortar		
	7 Days	28 Days	90 Days	7 Days	28 Days	90 Days
	1,624	2,547	4,926	1,878	2,847	4,847
	1,687	2,595	4,579	1,832	2,809	5.050
	1,732	2,611	4,684	1,854	2,789	5,035
Av.	1.681	2,585	4,729	1,855	2,815	4,977

The mixing was done in a small galvanized iron pan, enough materials having been used to make 9 specimens at one time. The sand and cement were first mixed dry, water was added and the whole was again thoroughly mixed. For the specimens containing 5 per cent, by weight of the cement, of diatomaceous earth and lime, these materials were first mixed dry with the cement and sand, water was added and then thoroughly mixed again. The same amount of water was used throughout the tests for all mixes, although with the admixtures the mortar became slightly drier in consistency than the others.

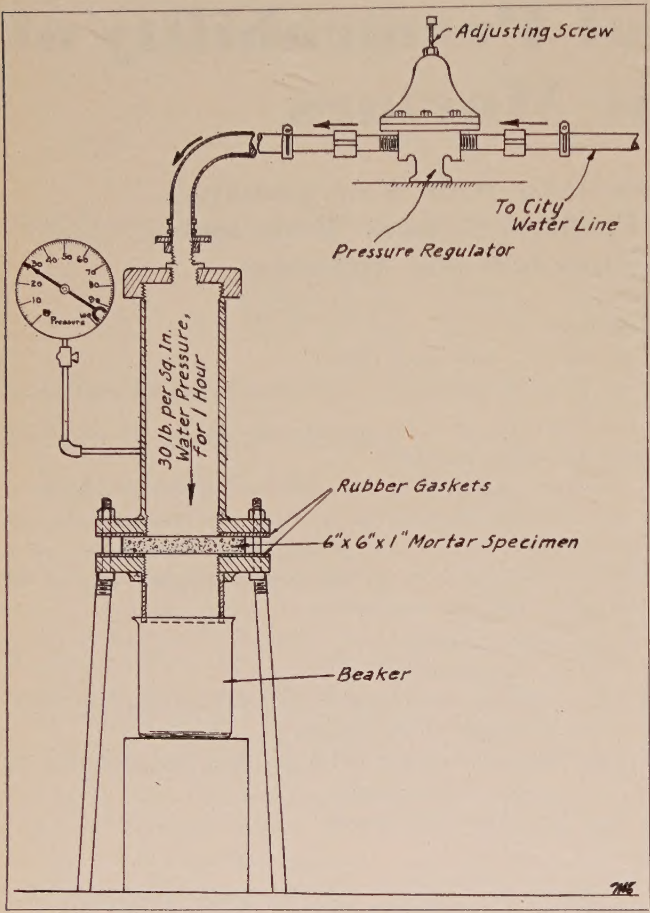

Figure 1. Apparatus for testing permeability of mortar specimens

The mortar, after being thoroughly mixed by hand, was carefully rodded in special molds, in layers of about 1 in. in thickness, care being taken not to ram the mortar. The molds were waxed and oiled, to prevent absorption of the water, paper being used to line the sides, so as to get a rough surface.

After remaining at laboratory temperature for 24 hours, the specimens were removed from the molds and cured in a moist, constant-temperature room at 70 deg. F., until the date due for testing. Before testing, the mortars were removed from the moist room and dried to constant weight. After drying and cooling, the specimens were placed under a working pressure of 30 lb. per sq. in. for one hour. The water line was connected directly to the city water pressure, a constant pressure being maintained at all times by means of a pressure regulator. The specimens were bolted down, between two pipe flanges, rubber gaskets being used at the top and bottom to prevent leakage, as shown in Figure 1.

TABLE 2—PERMEABILITY TEST RESULTS

	Composition		Cu. Cm. Passing Through per Sq. In.	Depth of Penetration of Water, in Inches	
	Cement	Admixture	7 Days	28 Days	90 Days
(a)	Super	None	(1) 0.0	(4) 0.687	(7) 0.375
			(2) 0.0	(5) .656	(8) .600
			(3) 0.0	(6) .688	(9) .380
			Av. 0.0	0.677	0.452
(b)	Portland	None	(1) 10.3	(4) 0.937	(7) 0.437
			(2) 10.0	(5) .812	(8) .625
			(3) 7.5	(6) .750	(9) .500
			Av. 9.2	0.833	0.520
(c)	Portland	5 per cent diatomaceous earth	(1) 0.0	(4) 0.718	(7) 0.250
			(2) 0.0	(5) .656	(8) .281
			(3) 0.0	(6) .625	(9) .500
			Av. 0.0	0.666	0.344
(d)	Portland	5 per cent lime	(1) 1.7	(4) 0.437	(7) 0.187
			(2) 1.9	(5) .468	(8) .250
			(3) 7.5	(6) .469	(9) .156
			Av. 3.7	0.458	0.198
(e)	Waterproofing cement	None	(1) 0.9	(4) 0.562	(7) 0.115
			(2) 1.1	(5) .500	(8) .125
			(3) 1.5	(6) .937	(9) .250
			Av. 1.2	0.666	0.163

Figure 2 shows a comparative graph of the depth of the penetration of the water on the different mortar specimens.

It will be noted from the foregoing tests that as the mortars age, the line of demarcation becomes less and less. On the 7-day Super Cement mortars, the water nearly

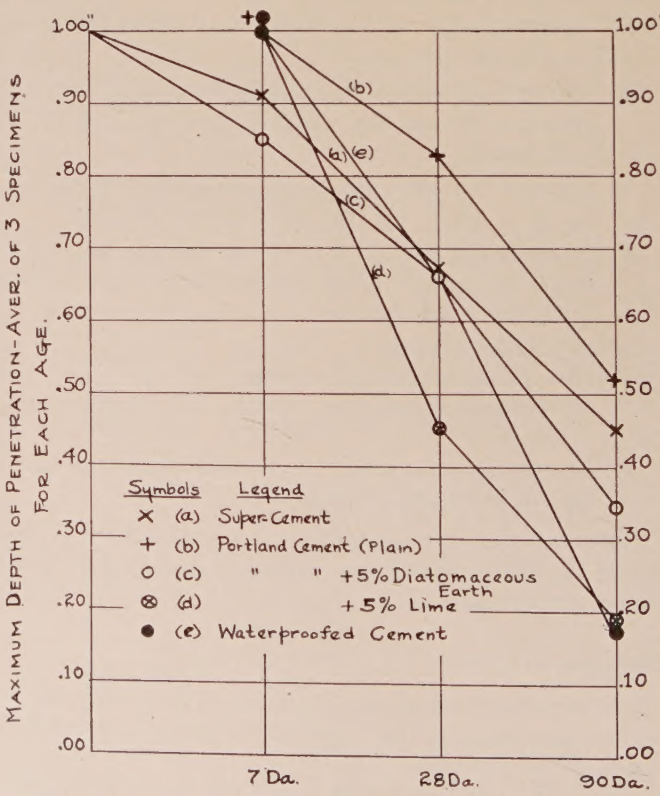

Figure 2. Water penetration within specimens for test of permeability

penetrated through the specimens, but at 28 days they show good impenetrability. In the 7-day lime and waterproofing cement mortar specimens the water penetrated through, but at the age of 28 days the depth of penetration is less than the 7-day mortars in which the water did not pass through. This also holds true for the 90-day specimens, which also show good imperviousness to water.

No tension or compression tests were made on mortars containing the admixtures, nor were any concrete test cylinders made of these materials.

Build Reinforced Concrete Houses with Standard Metal Forms

Forms of Full Story Height Permit Rapid Placing of Concrete—Bring Large-Scale Construction Methods into House Building Field

A TYPE of metal form work which permits concreting one story at a time has been found well adapted to the construction of monolithic reinforced concrete dwelling houses on the Pacific Coast and has been in successful use there for several years. Although the standardized forms employed have been used in the erection of several tall buildings, their most interesting application is seen in dwelling house construction, because to a considerable measure they bring large-scale construction methods into the field of small buildings.

Homes of Insulated Reinforced Concrete

The 5-room, one-story dwelling here described and illustrated is typical of a number of reinforced concrete homes built by the use of these forms—homes in which the outside walls are of double section with insulating material between sections, the interior partitions are of monolithic concrete, and both partitions and walls are so constructed that they serve as fire-stops between rooms.

Five-room reinforced concrete house with full-height basement under two elevated bedrooms, built with standardized steel forms

In the dwelling house shown in the illustration, the first concrete work consisted in the placing of the foundation walls to a height of 18 in. above grade. Then the entire area inside the foundation walls was filled with quarry waste, to a level about 4 in. below the top of the walls. After the fill had been well compacted a 4-in. reinforced concrete floor slab was placed over it, the surface of the floor having been made flush with the top of the walls.

Nature of Metal Form Units

With the first floor placed, the work was ready for the erection of the form work for the full height of the exterior walls and the interior partitions. This procedure will be understood best after considering the nature of the metal forms employed. The form units consist of wall panels made of No. 14-gauge sheet metal and fabricated in widths of 12, 18 and 24 in. and in lengths ranging from 1 ft. to 10 ft. Connecting angles are attached to each end of a wall panel, one angle being riveted to the panel and the other being detachable and fastened with flat-head bolts. Telescopic plates punched at 1-in. intervals are made to fit into any standard wall panel, either 12, 18 or 24 in. wide, and in lengths of 12 and 16 in. By removing the detachable angle on a wall form panel the telescopic plate is inserted and the full length of the panel is thereby adjusted to the exact length desired. In this manner lengths are adjusted to the nearest inch.

Special Corner Forms

Corner members for both interior and exterior corners are fabricated in a manner similar to the regular wall-form panels. The connecting flanges on the sides of the corner members are punched so that the wall forms can be connected to them at any given height. Connections between the corner members and the straight wall panels are easily and quickly made by means of a simple locking device. The corner members are made in lengths of 1, 2, 3, 4, 6, 8 and 10 ft.

Wall Ties and Special Accessories

Metal wall ties, made of No. 14-gauge steel and 1 in. wide, are placed between panels at vertical intervals of 2 ft. or less. These ties are held in place by wedges which pass through slotted holes in each end of the tie, and they are held to the forms by means of a notch in the wedge. Provision is also made at the center of each wall tie for holding the wall reinforcing bars in position. Special arrangements are also made for holding door and window frames in position, and for securing conduits, outlet boxes and plumbing and heating pipes to the forms so that they will not be displaced while the concrete is being placed.

Setting Forms into Position

When the first floor of the building illustrated had hardened for 24 hours the steel forms for one side of the walls and partitions were erected directly on the floor, to the full story height. The metal form panels were actually set on wooden mouldings made of 2 by 4's, these mouldings serving as forms for the concrete base moulds. The base moulds were thus made monolithic with the concrete walls and partitions. A small rough door buck was then concreted in place at all doors, and the concrete was bullnosed to return against it. All steel sash was likewise set into position and securely fastened. Conduits, plumbing pipes and steel reinforcing bars were likewise placed and secured.

All the work just mentioned was, of course, set in position and secured while only one side of the wall and partition forms were in place. The other side of the form work was now placed, and the wall ties were wedged into position.

Ceiling and Roof Construction

In the meantime the exposed redwood ceiling beams and panels for the living room, dining room and hall were stained and waxed and set into their final position. Each of the remaining rooms was roofed over with the final flat roof construction, with clear openings left over all partitions and walls.

Concrete Vibrated with Rubber Mallets

In the concreting operation the flat roof construction was then used as a runway and the concrete was dropped through the openings just mentioned. During the placing of the concrete three men remained below, for the purpose of vibrating the concrete into position by hammering the forms with rubber mallets. An ordinary platform hoist was used to lift the concrete buggies from the ground to the roof level.

How Wall Is Insulated

Special mention should be made of the manner in which the exterior wall is insulated between the inner and outer part of the wall. When the walls and partitions were concreted in the main concreting operation, only the inner part of the exterior wall was placed. That is, the outer forms were set to form the outer face of the inner section of the double wall. The wall ties, however, extended out far enough to engage the outer forms when set into their final position.

After the inner section of the exterior wall was concreted, the outer forms were removed and the surface of the half wall was brushed with a coating of asphalt waterproofing compound. Then a 1-in. thickness of insulating material; on one side of which a heavy roofing paper was attached, was applied to the brush coat in strips 2 ft. wide and 10 ft. long. The steel reinforcing bars for the outer section of the wall were then placed and held in position by the wall ties, after which the outer wall forms were reset in their final position and the outer section of the wall was concreted. This method of construction, it will be seen, produces an exterior wall with heavy insulation and with the two sections of the wall bound together by the metal wall ties.

Upon removal of the forms the wall surface was wire-brushed, and a colored cement stucco was applied to the exterior, and a ¼-in. coat of plaster to the interior wall faces. The ceiling, aside from the rooms that have beam ceilings, was made of metal lath and plaster.

Speed and Economy in Concrete Work

Up to the time of the removal of the forms and their wire-brushing, the concrete work had required only 9 days of the labor of one carpenter and 5 unskilled workmen, except that 3 additional laborers were employed for 6 hours on the day when the walls and partitions were concreted. The total outlay for labor in connection with the concrete work, including setting and removing forms, mixing and placing concrete, setting steel reinforcement, and wire-brushing the concrete, was less than $400, including the proportionate amount of the superintendent's time.

Acknowledgment

The steel forms employed on this work were developed and fabricated by the Steel Speedform Co., of Berkeley, Calif.

Vibrated Concrete One of A. C. I. Major Convention Topics

The subject of vibrated concrete will receive marked consideration at the forthcoming American Concrete Institute convention, when at least one session will be devoted to it.

Laboratory and field data will be presented and numerous experiences in the use of various types of vibrating equipment, type of section, and kind of concrete will be reviewed.

Sessions of the 1933 meeting are to be held at the Palmer House, at Chicago, from February 21 to 24. Minimum room rates of that hostelry will prevail for Institute members, no matter what accommodations are assigned.

The program committee's tentative outline is as follows: Tuesday afternoon, first technical session; Tuesday evening, second technical session; Wednesday afternoon, Planetarium and Century of Progress exposition, then nearing completion; Wednesday evening, third technical session; Thursday morning, vacant period; Thursday afternoon, fourth technical session; Thursday evening, dinner; Friday morning, business and fifth technical session; Friday afternoon, sixth technical session, adjournment.

A. S. T. M. Regional Meeting Scheduled for New York in March

The 1933 regional meeting of the American Society for Testing Materials is to be held in New York City on March 8. The decision to hold this meeting in the East was influenced by the fact that the 1933 annual meeting is to be held in Chicago.

Group meetings of committees are to be held in New York at the same time, on various days during the week beginning March 6.

Precast Light-Weight Concrete Slabs Placed on Capitol Dome

Reconstruct Dome of Illinois State Capitol — Precast Units Weigh Only 14 Lb. per Sq. Ft.—Design, Manufacture and Placing of Slabs

THE re-roofing of the state capitol building dome at Springfield, Illinois, with large precast slabs of light-weight reinforced concrete provides an excellent illustration of the market possibilities in special products of this character.

In this reconstruction work the old roof covering, which consisted of zinc and copper sheet metal on wooden sheathing is being replaced by precast concrete slabs covered with new zinc which follows precisely the same contour as the old covering.

Some Concrete Cast in Place

All the old steel and wrought iron work that is utilized in the reconstructed roof has been carefully examined. Loose and imperfect bolts and rivets have been replaced, and joints that were found to be weak were strengthened by electric welding.

A small amount of new concrete work was cast in place, notably in the roof slab over the stone balcony around the lower part of the dome. This concrete work, also made with light-weight aggregate, replaces the old sheet metal-clad wooden roof construction.

Slabs Have Double Curvature

The precast concrete roof slabs, which weigh only 14 lb. per sq. ft., were cast with a double curvature. That is, the slab surface was curved horizontally to conform to the circular plan of the dome, while the vertical curvature naturally was made to conform with the vertical curvature of the dome. From this it will be seen that the slabs in each horizontal tier differ from those in every other tier, both as to length and as to curvature.

Design and Manufacture of Slabs

All slabs were cast with a uniform width of 18 in., certain "specials" excepted, while the maximum length is approximately 10 ft. The slabs have two ribs—one near each edge—each reinforced at both top and bottom with ½-in. round deformed bars. The purpose of the double rib reinforcement was that of preventing breakage in shipment and handling. The web between ribs was reinforced with 3- by 3-in. No. 14 galvanized welded wire fabric. The design of the ribs contemplates a working load, or roof load, of 50 lb. per sq. ft. of actual surface area, whether the slab is right side up or inverted.

The mixture used in the manufacture of the slabs consisted of 1 part of cement to 4¼ parts of haydite whose fineness modulus was 3.90. The water content was 6 gal. to the sack of cement. The concrete, which weighed 100 lb. per cu. ft., was vibrated into place by means of a vibrating tool having 3,600 r.p.m.

Load tests were applied to the precast slabs on the construction site. The test load was specified to be 2½ times the live load, plus the dead load. For a slab 8 ft. long (having 12 sq. ft. of surface area) this required a uniformly distributed test load of 1,500 lb. plus the dead load, or nearly 1,700 lb., or a loading of half that amount concentrated at the mid-span. The loads were applied by means of sacked cement piled on the mid-span of the slab under test. All slabs took the test without showing signs of distress.

Placing and Anchoring

When the slabs were placed they were anchored to the main wrought iron ribs by means of ⅜-in. carriage bolts with plate-and-lock washers. All anchor fastenings were galvanized. Joints between slabs were tongue-and-grooved and were pointed with a sand-cement grout. The sheet zinc covering was anchored to special vertical steel ribs spaced at regular intervals around the dome and anchored, in turn, to the main framework of the dome.

Progress of work on October 27, showing first precast concrete slabs in place on main dome

Acknowledgments

The precast slabs were manufactured by the Geo. Rackle & Sons Co., of Cleveland, Ohio. The reconstruction work was built under the direction of C. H. Hammond, state supervising architect, with Bryant E. Hadley as supervising assistant in immediate charge of supervision. Cornelius W. Macardell was architectural assistant and E. G. Schwarz was superintendent of construction. Frank A. Randall, of Chicago, was consulting engineer, with E. A. Randall as structural engineer in charge. Charles Bostrom was the engineering representative of the secretary of state, who has official custody of the building.

Muskegon's Concrete Laboratory Saves Money for City

Figures Determined from Contractors' Bids Show Saving on City Paving Work Much Greater Than Cost of Installing and Operating Laboratory—Extend Testing Service to Surrounding Territory—No Charge for Local Service

A CONCRETE laboratory enjoying enough success to warrant free tests to contractors, concrete products manufacturers and construction departments of some of the larger industrial plants is the experience of the laboratory conducted by the Public Works Department of Muskegon, Michigan.

For some years prior to 1927 the engineering officials of Muskegon were uncertain about the quality of paving materials and design and quality of the pavements constructed by individual contractors. They felt that some accurate check should be instituted.

The first step taken by H. J. Lewis, city engineer, was to send Fred Lederer, his assistant, to a concrete school conducted by the Portland Cement Association in Detroit. To work out the results obtained at the school a makeshift laboratory was set up in the basement of the city hall. This proved so successful that a separate building was authorized by the city commission at a cost of $4,500.

The Laboratory Equipment

Included in this new laboratory was the following equipment:

A Watson-Stillman compression machine of 100 tons capacity;
A Rotap sand shaker;
Two sets of Tyler standard sieves;
One torsion balance; 1,000 grams capacity;
One analytical balance; 500 grams capacity;
One analytical platform scale; 200 lb. capacity;
One constant temperature oven;

Added to this was the complete equipment necessary to make the standard tests of the A. S. T. M. for concrete and concrete materials.

Again success followed, and additional equipment for testing asphalt and asphalt materials was installed at a cost of $2,000. Later the city gas tests and the water analysis were done in the laboratory.

Wide Scope of Testing Service

Charges to customers until 1930 were $3.00 per hour. Among the tests undertaken for contractors, products manufacturers and others were sieve analysis of aggregates; specific gravity; unit weight; decantation and colorimetric tests; absorption and moisture contained in the aggregates; yield, density, consistency, and other experimental tests for quality and economy through use of different combinations of aggregates; compression tests of 6 by 12-in. cylinders and other standard tests of the A. S. T. M.

Besides the local customers the laboratory makes tests for the Muskegon County Highway Department, the Michigan State Highway Department, Ottawa County Highway Department, and for material companies and concrete products manufacturers in some of the surrounding towns and cities.

Local Service Free

Two years ago Mr. Lewis decided that if free service were given locally it would tend to make contractors and products manufacturers more willing to bring their products for tests, which would result in a better quality of concrete throughout the city and create good will between the city administration and the contractors. This belief proved true. Better concrete work has been evident in the city, and an ever growing co-operation has developed between the engineering department and the contractors and products manufacturers.

Actual Savings in Dollars and Cents

On full-width concrete pavements only, the city, since 1926, has saved a total of $32,202.59 through the operation of this laboratory. The laboratory has shown in every instance that in awarding construction jobs the more economical method has been that in which the city furnished the materials. Previous to the installation of the laboratory the contractor bid two ways—he to furnish materials, labor and equipment, or the city to furnish the materials and the contractor to furnish labor and equipment. At the completion of each job a comparison was made between the contractor's bid which included materials, labor and equipment, and the bid which included only labor and equipment, with the city furnishing the materials. In each case the laboratory proved that the second method was the more economical. It was on these figures that the savings to the city were determined.

The extra cost of maintaining the laboratory in 1931, a typical year, was only $1,042.60, plus the cost of electricity, gas and water. This figure included $169.00 for materials and $873.60 for a laboratory assistant. The laboratory is in charge of Fred Lederer, assistant city engineer, who is aided by one laboratory assistant.

Laboratory Pays for Itself

The laboratory is located in the city "yards," only a short distance from the heart of the down-town business district, and is easily accessible. Both Mr. Lewis and Mr. Lederer are enthusiastic about the work now being done, and they feel confident of the future worth of the venture begun five years ago in the basement of the city hall. In this short time it has more than paid for itself, both in actual savings and in the quality of construction work.

Place Colored Concrete Floor Finish by Unique Method

Tile and Flagging Effects Obtained by Cutting Joints in Topping—Surface Scored to Simulate Natural Products—Application of Color and Wax Finish—Working Procedure

By G. E. WARREN
Assistant General Manager, Portland Cement Association, San Francisco, Calif.

Reddish brown concrete floor, with colored wax finish, in week-end ranch house of Ernest E. Duque, Montecito, Calif.

A UNIQUE method of constructing concrete floors, to produce beauty as well as utility, was developed recently by Edwards and Plunkett, architects, and Charles M. Urton, contractor, of Santa Barbara, Calif., in constructing a week-end ranch house for Ernest E. Duque, Fernald Point, Montecito, Calif.

Cuts Joints in Mortar Topping

Over the structural slab a 1:2 cement-and-sand mortar topping was placed to a thickness of ⅝ in. This was colored with mineral oxides to produce the desired decorative effect. After being placed, it was screeded off and finished to simulate the somewhat irregular texture of floor tile. When the topping had stiffened enough to support knee boards, joints exactly 1 in. wide were cut in the topping with a tool made of ordinary table knives bolted on each side of a 1-in. block of wood, and run along a straight-edge. In the residence floor illustrated, the joints are 12 in. apart. As the joints were cut, the loose mortar was removed with a knife blade.

The Wax Finish

After the slab had cured for 12 hours, the open joints were pointed with a 1:2 mortar made with white portland cement and sand. When the mortar "tiles" and joints had hardened, a natural colored floor wax was applied in two coats to the joints; and a mixture of equal parts of red and brown, also in two coats, was applied to the squares or "tiles," to produce a color variation similar to the red tiles on the stair treads.

Flag-Like Design on Terrace Pavement

An interesting flagging effect was obtained on an outside terrace by using the joint-cutter to mark out irregular, flag-like designs in the 4½-in. concrete slab, which was colored with mineral oxides to resemble sandstone. To enhance the stone-like appearance of the concrete flagstone, a mixture of adobe and pebbles was lightly scattered over the floated surface. Then the plastic surface was scored with a tool made of a piece of 2-by-4 about 4 ft. long with 12d nails driven through it and the ends bent over. By drawing this tool over the surface, a series of parallel marks was produced very similar to the effect produced when stone is tooled. The joints were then cut out before the concrete had hardened, and after the hardening was sufficient to permit the use of knee-boards without damaging the surface the joints were pointed with a 1:2 white portland cement-sand mortar.

It is estimated that the interior floor in the "tile" effect was constructed for 30 cents per sq. ft., while the terrace floor, with the flagging, cost around 25 cents per sq. ft.

Tests of Light-Weight Slabs for Highway Bridge Floors

The Division of Tests of the Bureau of Public Roads has recently completed a series of static load and impact tests on two bridge floor slabs of a rather unusual type. These tests were undertaken at the request of the Bureau of Public Works of Allegheny County, Pa., and were carried out as a co-operative project with that organization, according to an article by L. W. Teller and G. W. Davis in the September (1932) issue of *Public Roads*, a monthly publication issued by the Bureau of Public Roads of the U. S. Department of Agriculture.

The slabs tested are a combination of steel shapes in the form of a grating or mat which, after erection, is filled with portland cement concrete. The features of particular interest are the small depth, 3 in.; and the moderate weight, between 50 and 55 lb. per sq. ft. The advantages of a bridge floor slab having these characteristics are obvious.

Static load tests on small sections of a slab of this general type had indicated that such construction possesses flexural strength sufficient to warrant its consideration for use in the design of highway bridge floors, but there was some question as to whether or not the impact of the wheels of motor vehicles might break the bond between the steel and the concrete, thus weakening the slab structurally and also permitting the entrance of moisture between the two materials.

The primary object of the tests carried out by the Bureau of Public Roads was to determine to what extent severe motor-vehicle impact would affect the structural strength of bridge floor slabs of this type.

To obtain this information a definite schedule of static loads was applied to the slabs before, during, and after the program of impact loadings to which they were subjected. Deflection and strain measurements for each static loading made possible comparisons of the structural action of the slabs before and after receiving impact.

Conclusions

From the data which have been presented and from observations made during the investigation the following conclusions are drawn.

1. That both slabs acted as stiff plates giving a good distribution of the load to the supporting structure.
2. That both slabs were capable of supporting static wheel loads such as are normally found in present-day traffic, without excessive stress.
3. That the effect of the severe impact which was applied during the tests was to increase the flexibility of the structure and to decrease the distribution of the load. This effect was more marked in the first slab than it was in the case of the second slab.
4. That there was nothing in the behavior of the slabs under static loads subsequent to impact to indicate that either slab had been damaged structurally by the impact.
5. That there was no loosening of the concrete by the impact.
6. That, for durability in exposed locations, the steel in the upper surface of the slabs should have more protection from moisture than was provided in the slabs tested.

Wabash Portland Cement Company to Make Super Cement

The Wabash Portland Cement Company, with plants at Stroh, Indiana, and at Osborn, Ohio, is taking up the manufacture of Super Cement.

Cement companies now producing this special product include the Peerless, Bessemer, Vulcanite, Lawrence, Marquette, Dewey, Kosmos and Wabash.

Maintenance Cost of Concrete Streets

By **ARTHUR L. BOLEY**
City Engineer, Sheboygan, Wis.

SHEBOYGAN, Wis., is very proud of its streets, and the city has had remarkable success with its concrete pavements. This type of pavement has been placed almost exclusively since 1911, as a result of which the city now has 1,280,000 sq. yd. of concrete streets. The tabulation given shows the number of square yards laid each year, beginning with 1911 and including all but the last few months of 1932.

Low Maintenance Costs Shown

The economy of this type of street pavement from the standpoint of maintenance costs will be appreciated by city engineers and others who deal with roads and street pavement, when our extremely low maintenance costs are considered.

The maintenance cost over the 21-year period covered by this record has averaged less than one-seventh of one cent per square yard per year. During all this time the streets have been well kept up and all cracks have been kept sealed.

Due to the age of many of the streets, the cost of maintenance is slowly increasing, as would be expected, and in 1931 it was slightly more than one-fifth of a cent per square yard. During the entire 21-year period maintenance of these pavements has cost the city only $17,618.39.

The maintenance costs here given have been taken from the records in the office of the city engineer and checked with the records of the city comptroller.

SQUARE YARDS OF CONCRETE PAVEMENT PLACED IN SHEBOYGAN, WIS.

Year	Yards Laid	Total Yards to Date
1911	19,860.39	19,860.39
1912	26,277.60	46,137.99
1913	21,788.22	67,926.21
1914	52,139.11	120,065.32
1915	101,423.93	221,489.25
1916	53,033.16	274,522.41
1917	27,704.17	302,226.58
1918	37,017.20	339,243.78
1919	26,942.69	366,186.47
1920	6,095.31	372.281.78
1921	67,238.00	439,518.78
1922	53,638.85	493,158.63
1923	68,250.74	561,409.37
1924	78,367.12	639,776.49
1925	98,850.00	738,626.49
1926	102,089.40	840,715.89
1927	117,088.01	957,803.90
1928	128,034.42	1,085,838.32
1929	117,263.45	1,203,101.77
1930	49,325.98	1,252,427.75
1931	22,092.49	1,274,520.24
1932	5,665.32	1,280,185.56

Painting on Concrete Surfaces

Materials Suitable for Painting and Methods of Their Application Covered in A. C. I. Report —Preparation of Faulty Surfaces—Organic and Inorganic Paints Classified—Portland Cement and Other Hydraulic Paints — The Question of Moisture

IF a concrete surface is covered with laitance, form-oil, soot, loosely held material or efflorescent salts, it is useless to expect satisfactory results with any paint, unless the surface is first brushed vigorously with a wire brush or lightly sand-blasted. This warning is contained in a report[1] of Committee 407 of the American Concrete Institute, compiled by F. O. Anderegg,[2] author-chairman of the committee.

After a further discussion of matters such as suction, green concrete, moist concrete, alkalies in concrete, and efflorescent crystal pressure, the report takes up in detail the major subjects of painting materials and methods of their application.

PAINTING MATERIALS

A variety of paints have been applied to concrete, ranging from cold water paints to nitrocellulose lacquers. Each material has its limitations, but some are much better than others. They fall into two large groups—those largely inorganic and those largely organic in composition.

The permeability of the paint film is very important in determining its successful use under various conditions. There are two schools of thought. One holds that moisture must be kept out of the concrete, insists on having a film as nearly impervious as possible; while the other school, realizing that moisture very often gets into the concrete from behind, believes opportunity should be provided for the wall to "breathe." If moisture has a chance to escape through pores in the surface paint, the film will not be pushed off as a whole by moisture coming through the wall from behind.

The ability of the paint material to transmit the salts in solution in the moisture affects the pushing off of the film by efflorescent crystal pressure. Damage will depend on whether the crystals grow on the outside of the film or back of it.

A. Largely Inorganic

These treatments are not generally applied with success to surfaces which have been painted with oil paints unless the latter have been completely removed.

1. *Cold water paints,* which usually contain lime with glue or casein as the cementing agent, together with pigments. Sometimes portland cement is added, but its hardening properties are reduced by the glue or casein. These paints are not suitable usually for exterior use, and where the concrete base gets damp, their durability is low, due to the decay of the casein or glue. Their use should be limited to dry, interior walls. These films are probably less permeable than those of cement paint, so that the accumulation of salts near the concrete surface often pushes the paint film off.

2. *Portland cement or hydraulic paints,* which contain a large amount of portland cement, suitable pigments and other ingredients. Some of these are diluted with more or less lime. The effect of the lime is to reduce the durability and to decrease the opacity when wet. On the other hand, the ease of spreading is slightly increased, as is the flexibility of the paint film. Sometimes organic waterproofing materials are added, which greatly increase the ease of spreading. If stearate is used the durability is probably not impaired, but the effect of other waterproofing admixtures in this regard has hardly been satisfactorily demonstrated.

Portland cement paints are suitable for inside and outside application to walls, but are not recommended for painting floors except the floors of swimming or wading pools. These paint films offer reasonable resistance to the weather, often effecting a perceptible improvement in this regard over the original surface. These films are not impermeable to the passage of moisture, so that a wet wall has a chance to "breathe" or dry out. Any efflorescent salts in the concrete tend to pass through the cement film to be deposited on the surface without much damage to the paint.

3. *Proprietary chemical treatments,* whereby colored stains, mostly inorganic, are deposited within the pores and over the surfaces of the concrete. Very beautiful effects are claimed for these methods, but their best application would seem to be for interiors, for most of the compounds deposited are susceptible to weathering, resulting in gradual fading. The permeability of the surface to moisture is reduced by this treatment by an estimated one half to three fourths, but the nature of the deposit does not lead to probable detachment by crystal pressure or by moisture coming through the concrete from behind. Unless concrete in contact with the ground or other source of moisture has been waterproofed, a deposit of efflorescent salts often causes a fading of the colors.

B. Largely Organic

These paints are best applied in warm, dry weather.

1. *Oil paints,* which are composed of a vegetable drying oil vehicle, pigment and sometimes solvents or gums. The oils vary from linseed, which is probably most easily saponified by the alkalies found in concrete, to tung (china wood) oil, which seems to be least affected by these reagents. Hence the increasing popularity of the latter and the efforts to produce this oil in the southern part of this country. The former seems to be, however, more durable against weathering.

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[1] *Journal* of the American Concrete Institute, Sept., 1932, pp. 1-7.

[2] Consulting specialist on building materials, Pittsburgh, Penna.

The gums may vary from resin through the resin esters, the fossil gums to some of the new condensation resins. Sometimes these require special plasticizers and solvents which are added in conjunction with the drying oil. The gums vary in their degree of resistance to the action of alkalies and to weathering. The permeability of these drying-oil films is slight, so that the film may be bodily displaced if the concrete becomes wet. When solvents are used, it is difficult to fill completely the larger pores in the concrete.

Paints containing aluminum powder alone or in conjunction with other pigments have been applied with apparently satisfactory results on a number of jobs. The reflecting power of the aluminum reduces the deterioration of the film by light, but on the other hand, the presence of the leafed-out metal probably lessens the opportunity of moisture escaping from the concrete. A bituminous-aluminum paint has been developed for giving a decorative finish to a bituminous waterproofing treatment of concrete. Another somewhat similar treatment involves alternate coats of vegetable drying oil and micaceous sands.

2. *Lacquers*, which usually contain synthetic plastics as bases, suspended in suitable solvents with the aid of plasticizers. Very often all of the materials entering these lacquers are synthetic. The most notable examples of these plastics are cellulose nitrate or acetate. These have apparently low permeability and therein seems to lie their danger, for the whole film is readily pushed off the concrete surface by moisture in the concrete. Glyptol and phenol resins are also frequently utilized in this way.

Certain of the vinyl resins have been used with fairly good success on concrete. Some of the films allow moisture to evaporate to some extent and when properly applied become mechanically well bonded to the surface. They have, however, a tendency to darken a bit on exposure to light. A number of other materials are coming on the market, but opportunity to make adequate tests has been lacking.

3. *Hybrides*. In order to get better bond between the cellulose esters and concrete surfaces sometimes vegetable oils or some of their fatty acids are added. These admixtures greatly increase the rate of penetration into the concrete, allowing the film to secure a much more effective mechanical anchorage with marked improvement in quality, but the corrosive action of unsaturated fatty acids on portland cement products must not be disregarded.

4. *Conclusions*. Where the concrete is quite dry and free from moisture ingress from behind, an oil paint of a high degree of impermeability may be used to advantage; but where moisture is likely to get into the concrete, a paint that is porous enough to permit the moisture to evaporate is likely to give better satisfaction.

METHODS OF APPLICATION

The wide variation in nature of the painting materials applied to concrete requires special methods of application.

Generally speaking, the paints of largely organic character may not and must not be applied to damp concrete surfaces. The concrete should have aged until the alkaline reaction has been largely neutralized or some treatment such as fluosilicate should have been given it, and it should be allowed to dry out pretty thoroughly. The importance of obtaining adequate mechanical anchorage should be emphasized; a priming coat should be selected which penetrates well down into the concrete.

Coldwater paints are generally applied to a surface more or less dry; as their setting-up depends mostly upon a drying action, the presence of excess moisture is not desirable.

For the production of chemically precipitated color treatments the concrete should not be moist, because the action depends upon drawing of the solutions down into the pores.

Portland Cement Paints

With portland cement paints, mechanical anchorage is not so essential, because the cement bonds to the surface in the same way in which the concrete itself has hardened; but a highly troweled, smooth surface should be roughened a bit to give proper bond.

To obtain the best possible results with portland cement paint the wetting of the concrete surface and the subsequent curing of each coat of paint are highly important and must be carefully carried out. The following points are essential:

The surface must be moistened before the paint is applied, and the first coat of paint should be wet down as soon as possible after the paint is hardened sufficiently to prevent injury to the surface.

Before the second coat is applied the first coat should be dampened by spraying. The second coat of paint should be moistened with a fine spray as soon as it is hardened sufficiently to prevent the surface from being marred and should be kept wet as long as practicable.

During warm, hot and windy weather the paint film will harden or "set" quicker than during cool or cold weather, so that the paint film will need to be sprayed during the warmer weather sooner than during the colder weather. In order to get the best results under these conditions it is wise to make the application in the evening.

R. F. C. Loan Procedure Explained in Pamphlet

As a means of facilitating the preparation of data and the submission of applications in connection with obtaining loans from the Reconstruction Finance Corporation for self-liquidating projects, the R. F. C. has issued a 10-page pamphlet explaining the method of procedure.

The principal title of the pamphlet is "Financing the Construction of Self-Liquidating Public Projects." Various sections explain the types of projects considered eligible, the meaning of "self-liquidating," how to apply for a loan, where applications should be sent, and how applications are examined.

Requests for copies of this useful pamphlet should be addressed to the Reconstruction Finance Corporation, 1825 H Street N. W., Washington, D. C. It is suggested that request be made at the same time for copies of Circular No. 3, prepared by the Engineers' Advisory Board of the R. F. C. This circular outlines the information required by the R. F. C. Because of the varied nature of the projects for which loan applications have been made, no standard application forms have as yet been prepared.

EDITORIAL

Cement-Bound Macadam for Secondary Roads

THE article by U. J. Eckman, headed "Experimental Road Opened in Twelve Hours," printed in the November issue of "Concrete," gives expression to the renewed interest in cement-bound macadam construction for secondary roads.

The half-mile stretch of road described by Mr. Eckman was built by the Pennsylvania Department of Highways in July of this year, a special temperature-resisting cement having been employed. The construction method described is one of the approved methods for cement-bound macadam.

The Pennsylvania Department of Highways, later in the year, placed another experimental stretch of 18-ft. road in Northampton County, between Bath and Moorestown, in which the Hassam type of cement-bound macadam construction was employed.

The Hassam type of pavement was built quite extensively in New England more than twenty years ago. It was a patented method, but the patents have now expired. Many of the New England roads built as long ago as 1907 are still giving good service, but others had been placed carelessly, without complete penetration of grout and with uneven surfaces. In the meantime the concrete road and equipment for its construction came into the picture, and the Hassam type fell into gradual disuse.

Now the Pennsylvania Department of Highways believes that, by the application of modern highway engineering, durable roads can be built in cement-bound macadam. The mile stretch of road built by the department was placed in seven days, and in the last three days the average progress exceeded 1,000 ft. per day. The complete cost was about 95 cents per square yard, comparing favorably with the average cost of water-bound macadam construction.

Not only in Pennsylvania, but in Wisconsin, Ohio, New Jersey, Massachusetts, Rhode Island and other states, this year has seen the construction of experimental roads of cement-bound macadam. In several cases special invitations were extended to highway engineers of other states to observe the work under construction.

Engineers will observe the performance of the newly-placed cement-bound macadam roads, in order that the most efficient methods and equipment may be applied to their construction. In addition, they are investigating the present condition of some of the old Hassam pavements in the East which were placed in the period from 1907 to 1916 and are still giving excellent service. From these studies and observations sound conclusions can be drawn.

Cement-bound macadam has great possibilities as a durable and smooth-riding pavement for low-cost secondary roads, especially in localities where aggregates of suitable toughness are available. Highway engineers are to be commended for the energy and initiative they are displaying toward giving this type a chance to prove its worth under modern traffic conditions.

Keep Concrete Warm While Hardening

AN engineer reader of "Concrete" has suggested the possibility that the editorial on this page published in the November issue under the heading "Heating Coarse Aggregates in Warm Weather," might encourage carelessness about making suitable provision for an unforeseen drop in temperature.

When concrete is placed at any season during which cold weather may come, canvas or other means should be provided to inclose or cover the work, and some means should be on hand to heat the inclosure if necessary. It is also true that when concrete is placed during the late fall, the winter or early spring seasons, the water and sand should be heated prior to mixing, even though the weather may temporarily be warm.

On the other hand, those in charge of the supervision of concrete work should recognize the distinction between a temporary warm period in mid-winter and a period of typical warm weather in mid-October or in the spring season. While in these cases the newly-placed concrete should be inclosed or covered, and kept warm by artificial means if necessary, it is a useless waste of the contractor's money to require him to pre-heat both the coarse and fine aggregates in a season when pre-heating of the water alone would be ample.

Supervisors of construction and writers of specifications must look at the problem from all sides, if the contractor's interest is not to suffer from needless provisions and requirements.

As pointed out by A. C. Irwin on page 24 of the January (1931) issue of "Concrete," the specific heat of water is about four times the specific heat of aggregates and cement. In consequence, if the quantities assumed in Irwin's example are used in a mixture, and if the water is heated to 200 deg. F., the temperature of the mixed concrete will be not less than 60 deg. F. even if the temperature of the aggregates and cement is as low as 15 deg. F.

The Irwin formula can be verified by experience. It gives further support to the belief that pre-heating of water alone will take care of moderately cold weather, provided always that after the concrete is placed it is kept warm until samples show that proper strength has been attained.

PROGRESS—In a Page

Current activities in research, in matters pertaining to concrete and cement, as being carried on or completed by various organized groups.

Plan Third Inspection of Cement Laboratories

THE Cement Reference Laboratory, a joint project of the government and A. S. T. M. Committee C-1 on Cement, will soon start a third inspection tour among cement testing laboratories. Those laboratories which desire such inspection should address their requests promptly to the Cement Reference Laboratory at the U. S. Bureau of Standards.

It is expected that laboratories desiring reinspection will refer to the reports of the preceding inspection, remedy the defects mentioned, if any, and advise the Cement Reference Laboratory that the needed improvements will have been made prior to the inspector's visit.

The tolerances for cement testing equipment are contained in the A. S. T. M. Standard Methods of Testing Cement (C 77-32). A laboratory can readily check and adjust its equipment for compliance with the specification tolerances. Such action would facilitate the inspector's work.

C. E. S. A. Standards for Concrete, Cement and Reinforcement

AMONG the standard specifications issued by the Canadian Engineering Standards Association the following have application to portland cement and to plain and reinforced concrete work:

A23-1929. Standard Specification for Concrete and Reinforced Concrete.

A5-1927. Standard Specification for Portland Cement (second edition).

C14-1924. Standard Specification for Reinforced Concrete Poles.

G30-1930. Standard Specification for Billet-steel Reinforcing Bars (second edition).

G31-1930. Standard Specification for Rail Steel Reinforcing Bars (second edition).

G32-1930. Standard Specification for Steel Wire for Concrete Reinforcement (second edition).

The first of the standards here listed is priced at $1.00 per copy; the others are 25 cents each. Copies may be obtained from the C. E. S. A., whose new address is 79 Sussex St., Ottawa, Canada.

A. S. A. Adopts Standard on Floor Forms

A NEW standard on Forms for Concrete Joist Construction Floors (A48-1932) has been approved by the American Standards Association. It covers the main dimensions of removable and permanent forms, pans, or domes made of wood, steel, or other material used in concrete ribbed floor construction.

The standard is the same as the recently approved Simplified Practice Recommendation R87-32, which is a revision of R87-29.

Copies may be obtained at 5 cents each from the Superintendent of Documents, Government Printing Office, Washington, D. C.

University Extension Course in Estimating Construction Costs

IN ANTICIPATION of an industrial revival, the extension division of the University of Wisconsin, at Madison, is offering the advantages of its training courses in the field of construction, given by correspondence study for men in any state.

This 20-assignment course entitled "Estimating Construction Costs," new this year, is being presented as a foundation study for men ambitious to advance in construction work.

The study is designed for the needs of estimators, engineers, designers, architects, and contractors. According to Professor H. E. Pulver, in charge, the course embodies the use of charts for recording the student's own cost data and simplifying his estimating problems with the least effort.

Wire Sizes of Aggregate Screens to Be Standardized

IN co-operation with manufacturers of wire screen and representatives of the concrete aggregate industry the Division of Simplified Practice of the U. S. Department of Commerce is working toward an agreement to reduce the number of sizes of wire used in the manufacture of screens for grading aggregates.

It is expected that a general conference will be held in Washington on or about December 15, for the purpose of obtaining final action on the proposed reduction in variety of wire diameters.

1932 Book of Tentative Standards

THE 1932 Book of A. S. T. M. Tentative Standards is now available. This special volume contains all of the tentative standards of the society, and it is the only publication which does contain them all.

The book comprises about 1,200 pages, including a complete subject index and a list of all A. S. T. M. standards and tentative standards.

Federal Waterproofing Specifications Canceled

Federal Specification SS-W-101, covering integral waterproofing materials for use with portland cement concrete or mortar, was canceled by the Federal Specifications Board at its meeting of September 20, 1932.

Co-Ordination of Basic Principles of Concrete Mixtures

Relation Between Fineness of Cement and Strength of Concrete and Mortar Covered in Eighth Article of Series on Technology of Concrete

VIII—Needed Laws of Mixtures and Known Fundamentals (Continued)

By JOSEPH A. KITTS
Consulting Concrete Technologist, San Francisco, Calif.

THE innumerable types of concrete mixtures, their many physical characteristics, the many physical characteristics of the ingredients, and the many conditions which affect the qualities, give vast scope to laboratory research of mixtures. Concrete research requires special facilities, special talent and the expenditure of much time, labor, and study. Therefore, research covering all the variables is costly and, as a result, the general data of physical measurements of mixtures and of the ingredients are very fragmentary, incomplete, and sometimes valueless for lack of essential records of the physical conditions.

As conditions, determined by the quality and physical characteristics of the materials and the technique and skill of testing, are rarely the same, the fragmentary data do not fit together readily to form a complete picture of the basic facts. Hence, the same ground has been retraced endlessly to find a path through the maze. The great obstacle to definite results from concrete mixture research has been the customary use of the antiquated, unscientific and erratic bulk-volume technique of proportioning in testing. It is necessary to resort to averages of the physical values of repeated or similar mixtures, in order to determine the definite laws of cause and effect from this principal source of data.

REVIEW OF MIXTURE RESEARCH
(Continued)

Fortunately, the very comprehensive studies made at Lewis Institute, of the effect of fineness of cement on the physical properties of concrete, furnish many repetitions of the same program of mixtures and physical measurements, and the general averages of these measurements show the definite laws of cause and effect not at first evident in the individual tests.

Effect of Fineness of Cement

Test Series Nos. 20, 31, 60, 118 and 120, made under the direction of Professor Abrams at Lewis Institute and described by him in *Bulletin* 4, S. M. R. L., and in *Proceedings,* Am. Soc. Test. Mats., 1919, constitute perhaps the most nearly complete record of the physics of mixtures.

Portland cements, from 7 mills, ground to 4 to 7 degrees of fineness giving residues ranging from 2 to 43 per cent on the standard No. 200 sieve, and comprising 51 different samples, were tested in neat mortars, sand mortars and concretes. Various types and sizes of aggregates were employed. The record covers 6,125 compression tests of concrete, 9,000 compression and tension tests of mortar, and several thousand miscellaneous tests of cements, aggregates and concretes.

Thoroughness of Record of Abrams Tests

An unusual feature of this record, particularly of Series 120, is the thoroughness of the measurements of the characteristics of materials and concretes. Nearly complete physical and chemical tests are given for the cements; ample physical measurements of the aggregates are provided; measurements of the concrete include strength, density, elongation and contraction, consistency, slump, water-cement ratio, and yield; and other values are readily calculated from the quite ample data. This record merits thorough exploration by students of concrete physics.

Information is presented on the effect of the fineness of cement under the following conditions:

(a) Effect of fineness, brand and quantity of cement, and of consistency of mix, on the strength, density, yield, workability, and water requirement of mortars and concretes, for residues of 2 to 43 per cent on the No. 200 sieve;

(b) Effect of fineness on the quality of concrete as determined by different brands of cement;

(c) Effect of size and grading of the aggregate;

(d) Effect of age of concrete;

(e) Elongation and contraction of concrete as affected by water and air storage; and

(f) The relation of water-cement ratio and strength as affected by different brands and fineness of cement.

Abrams' principal conclusions are restated briefly as follows:

1. The apparent effect of finer grinding of cement on the strength of concrete is: (a) dependent on other causes of strength efficiency for different cements; (b) generally, an increase of strength with fineness of a given lot of cement, for all mixes, consistencies, gradings of aggregate and age of concrete (two cements showed a decrease below 10 per cent residue); (c) increase approximately inversely as the residue on the No. 200 sieve; (d) greater increase for lean than rich mixtures; (e) greater increase at early than at later ages; (f) independent of consistency except lowered for very wet mixtures; (g) about 2 per cent increase for each 1 per cent reduction of residue on the No. 200; (h) acceleration of strength by acceleration of hydration; and (i) a shortening of the time of setting.

2. The normal consistency of cement is increased about 0.1 per cent of water (by weight of cement) for each 1 per cent reduction of residue on the No. 200 sieve.

3. The fineness of cement has no appreciable effect: (a) on the workability of rich mixtures as determined by the slump test; (b) on the yield and the density of concrete; (c) on expansion and contraction by wetting and drying.

4. The finer ground cements show greater slump in the leaner mixes and wetter consistencies of mix.

5. Concrete of all cements, mixes and consistencies showed expansion in damp sand or water storage and contraction in air. The lean concretes are slightly less affected than the rich mixtures.

6. The relative effect of fineness of cement on the strength of concrete is not appreciably influenced by the type or maximum size of the aggregate.

7. The unit bulk volume weight of cement decreases with fineness and varies from 76 lb. per cu. ft. (bulk volume) for 2.4 per cent residue on the No. 200 sieve to 108 lb. for 43.3 per cent residue.

8. One per cent increase of cement content gives about 1 per cent greater strength to the average mixture, is more effective in lean than in rich mixtures, is more effective in increasing the early strength, and the effect is independent of the consistency.

9. So long as the concrete is plastic or fluid and the aggregate not too coarse, the strength (for a given cement and aggregate) increases with decrease of water-cement ratio; and the water-cement ratio required for a given workability of mix is decreased by increase of cement content.

Abrams' conclusions, as interpreted in the foregoing, are appreciated as true and very important facts of the physics of mixtures. Exception must be taken, however, to his conclusion 13: "In using 94 lb. per cu. ft. as a uniform basis for proportioning the cements in these tests, the actual (?) volume of cement in a batch *of the same mix* varies about 35 per cent. If the mixtures had been proportioned in a manner that would have given a uniform (?) *volume* of cement, the resulting concrete strength would not have been so favorable to the finer cements"; and also, exception is taken to the explanation accompanying the tables of quantities of mixing water in the concrete, "Water reported on basis of true (?) volume of cement."

"Actual" volume, "true" volume, and "uniform" volume (question-marked by us) are used to describe the bulk volumes of cement represented by weights of 76 to 108 lb. per cu. ft. (loose bulk volume measure) as affected by bulking due to fineness of grinding of the cement. There is nothing new about this idea; it is the ancient rudimentary idea of volume of granular materials, employed by the foremost engineers of the ages and of today. No criticism attaches to Professor Abrams—the bulk volume idea of measure of granular materials in concrete is an ancient heritage which has been accepted as unquestionably as Holy Writ. But the bulk volume basis of measure and the bulk volume technique of testing are inaccurate, misleading and the cause of error and confusion in concrete research.

The cements of Series 120 do not depart materially from the physical and chemical standard (excepting fineness) and, thus, should have approximately the same apparent specific gravity, g, say 3.11. The absolute or true volume, V, of cement, as represented by the weight, L, per cubic foot bulk volume of the individual cement is expressed by the equation—

$$V = \frac{L}{62.4\,g} = \frac{L}{194 \text{ (appx.)}} \quad . \; . \; . \; . \; . \; . \quad (28)$$

The relations of weight and true (absolute) volume for the cements of Series 118 and 120 may not be expected to depart much from the values shown in Table 5.

The cubic foot bulk volume of cement K-1 is made up of 0.392 cu. ft. absolute volume of cement solids and 0.608 cu. ft. of voids or air space, and weighs 76 lb. The cubic foot bulk volume of cement L-5 is made up of 0.557 cu. ft. absolute volume of cement solids and 0.443 cu. ft. of air space, and weighs 108 lb. The ten other cements vary between these extremes. It should be obvious to the scientific student, upon examination of Table 5, that the bulk volume of granular materials is not a definite measure of the true volume of the solids, and that water-cement ratio and cement concrete ratio, based thereon, are indefinite, scientifically inaccurate and do not indicate the true relations of strength. This bulk volume basis of measure and technique of testing, which designates both—

$$\frac{1.0 \text{ c.f. water}}{(0.392 \text{ c.f. cement} + 0.608 \text{ c.f. air})} \text{ and}$$

$$\frac{1.0 \text{ c.f. water}}{(0.557 \text{ c.f. cement} + 0.443 \text{ c.f. air})}$$

as water-cement ratios of 1.0, is one of the major sources of error, discussed in the seventh article of this series, in the November (1932) issue. This accounts for the wide variations of strength of concrete for given water-cement ratios, as illustrated by Figure 1, *Bulletin* 1, S. M. R. L. The bulk volumes of aggregates, whether measured loose and moist, loose and dry, or dry and compacted, are the more prevalent and even greater sources of error.

It should not be inferred from the foregoing that 94 lb. of cement represents an accurate absolute volume of cement; it does not. However, as the apparent specific gravity of standard portland cement varies between narrow limits, about 3.1 to 3.2, no great error is involved in

TABLE 5

Bulking of Cement by Fineness of Grinding, and Equivalent Water-Cement Ratios

Cements of Series 118 and 120, *Bul.* 4, S. M. R. L.

Absolute Volumes Based on Apparent Specific Gravity of 3.11

Cement Ref. No.	Residue on Sieve No. 200	Weight, lb. per cu. ft. Loose Bulk Volume L	Absolute Volume per cu. ft. Loose Bulk Volume V	Proportion of Voids in the Unit Bulk Volume	Bulking of Cement $\frac{\text{Bulk Vol.}}{\text{Abs. Vol.}}$	Per Cent of the Absolute Volume in 94 lb. Cement	Equivalent cu. ft. of water to 0.485 cu. ft. Absolute Volume of Cement
K-1	2.4	76	0.392	0.608	2.553	81	0.81
L-1	7.1	82	.423	.577	2.366	87	.87
I-1	8.9	90	.464	.536	2.156	96	.96
K-2	9.4	84	.433	.567	2.309	89	.89
I-2	13.9	95	.490	.510	2.042	101	1.01
L-2	16.3	91	.469	.531	2.132	97	.97
K-3	17.7	91	.469	.531	2.132	97	.97
K-4	27.9	100	.515	.485	1.940	106	1.06
L-3	28.9	99	.510	.490	1.960	105	1.05
L-4	32.3	104	.536	.464	1.865	111	1.11
K-5	36.2	104	.536	.464	1.865	111	1.11
L-5	43.3	108	.557	.443	1.796	115	1.15

using a constant weight of this cement as the unit of volume.

Water-Cement and Cement-Water Ratios and Strength

Abrams presents, in Bulletin 4, a new form of water-cement ratio-strength equation—

$$S = \frac{D}{(W/C)^a} \quad \ldots \quad (29)$$

$$\text{or } \log S = \log D - a \log (W/C) \quad \ldots \quad (29a)$$

in which D and a (exponent) are constants for given cement and aggregate, age of concrete and conditions of production control. This is a "log-log" curve.

Abrams' original equation—

$$S = A/B^{w/c} \quad \ldots \quad (21)$$

$$\text{or } \log S = \log A — w/c \log B \quad \ldots \quad (21a)$$

is a "semi-log" curve.

Messrs. Hool and Pulver, in "Concrete Practice" (1926), approximate Abrams' original equation in the straight line form—

$$S = \frac{m}{w/c} + b \quad \ldots \quad (30)$$

in which m and b are constants for given cement, aggregate, age of concrete and conditions of production control for a limited range of water-cement or cement-water ratios.

Inge Lyse, in *Engineering News-Record*, November 5, 1931, proposed the use of the cement-water ratio, by weight, and the straight line equation—

$$S = m\,c/w + b \quad \ldots \quad (30a)$$

Lyse also suggests that the strength of plastic and workable concrete depends upon the concentration of cement in a unit of water and is directly proportional to this concentration.

Strength Varies with Absolute Volume of Cement

It is a logical deduction from available data that the strength of concrete, of given age, cement and aggregate, varies with the absolute volume of cement in a unit of cement-water mortar, but the strength-giving efficiency of the cement is not the same at all concentrations. As c/w is increased uniformly, the strength first increases at a slow and increasing rate, until c/w approximates 75 lb. per cu. ft. of water, and then increases at a decreasing rate with a maximum of strength at the maximum concentration of cement in the cement-water mortar; that is, the neat cement mortar of maximum density or normal consistency. Thus, there are two forms of curves expressing the cement-water concentration and strength relations, one (I) applying for c/w from 0 to 0.8, and the other (II) for c/w about 0.8 to 2.5, in which c represents the customary bulk cu. ft. of cement (94 lb.) and w is cu. ft. of water.

The author determines from Abrams' Series 120 that the equation of the No. I curve is—

$$S - K = KJ^{c/w} \quad \ldots \quad (31)$$

$$\text{or } \log \left(\frac{S}{K} + 1\right) = J'c/w \quad \ldots \quad (31a)$$

where $J' = \log J$, and that of the No. II curve is Abrams' first equation—

$$S = A/B^{w/c} \quad \ldots \quad (21)$$

The relative accuracy of Abrams' semi-log and log-log equations, Lyse's straight line equation, and the author's approximate semi-log equation has been determined by the author from the data of Abrams' Series 120, and is shown in Table 6.

Strength and Water-Cement Ratio Values

The strength and water-cement ratio values shown in Table 6 are averages of those values shown by cements K-2, K-3, K-4, L-1 and L-2. Water-cement ratios of approximately the same value and their corresponding strengths are averaged. The values include all consistencies and proportions of mixes given for the five cements. The values of the constants in the various equations are determined by the method of least squares and are, therefore, the most probable values in each case.

The equations as determined are—

$$\text{I} \quad \log \left(\frac{S}{700} + 1\right) = 0.49043\, c/w \quad \ldots \quad (31b)$$

$$\text{II} \quad \log S = 4.183046 — 0.974835\, w/c \quad \ldots \quad (21b)$$

$$\text{III} \quad \log S = 3.216308 — 1.631849 \log w/c \quad \ldots \quad (29b)$$

$$\text{IV} \quad S = 2992\, c/w — 1151 \quad \ldots \quad (30b)$$

$$\text{V} \quad S = 3600\, c/w — 1950 \quad \ldots \quad (30c)$$

I is based on the Table 6 values Nos. 8-13 inclusive, II on values 1-8, III and IV on values 1-13, and V on values 4 to 9.

TABLE 6.

Comparison of Empirical Equations of Relations of Strength, Water and Cement. Data from Series 120, Bulletin 4, S. M. R. L. Aggregate, 0 — 1-1/2 in. sand and pebbles from Elgin, Ill. W/C and strength are average values for cements K-2, K-3, K-4, L-1 and L-2. Strength values are averages of from 25 to 100 concrete cylinders. Cylinders stored in damp sand and tested damp. W/C = cu. ft. of water/89.6 lb. of cement.

	Average			Calculated Strengths					
Tab. No.	W/C	C/W	Compressive Strength lb./sq. in.	Curve I	Curve II	Curve III	Curve IV	Curve V	W/94 lb.
1	.526	1.901	4574	____	4680	4695	4537	____	.551
2	.576	1.736	4146	____	4184	4048	4043	4300	.604
3	.618	1.618	3836	____	3807	3609	3690	3875	.648
4	.683	1.464	3306	____	3290	3066	3229	3320	.717
5	.789	1.267	2645	____	2594	2423	2670	2611	.828
6	.889	1.125	2146	____	2073	1994	2215	2100	.933
7	.980	1.020	1674	____	1690	1700	1901	1722	1.028
8	1.075	.930	1330	1301	1365	1462	1632	1398	1.128
9	1.248	.801	995	1030	926	1146	1246	934	1.309
10	1.451	.689	819	826	587	896	910	530	1.522
11	1.611	.621	732	711	410	756	707	286	1.690
12	1.971	.507	554	541	183	544	366	____	2.068
13	2.572	.389	374	386	47	352	129	____	2.698

Abrams' original equation, $S = A/B^{w/c}$ (Curve II), is in satisfactory agreement with the test results for the usual limits for $W/94$ lb., of 0.5 to 1.3, or, for strength in excess of 1,000 lb. per sq. in. at 28 days. Series 120 shows that the water-cement ratio strength relation is independent of the cement content and consistency of the mix with given cement, aggregate, and technological conditions.

Appreciating the relative quality of cements and aggregates employed, and the technological conditions, as they affect the values of A and B, Abrams' equation $S = A/B^{w/c}$ satisfies our Requirement 2, within the practical limits of strength specifications, provided Requirement 1 is met.

Series 120 points definitely to Requirement 1, the law of the cement content, and will be presented in the next number.

(To be continued)

Gunite 12 Years Old Tests 16,700 Lb. in Compression

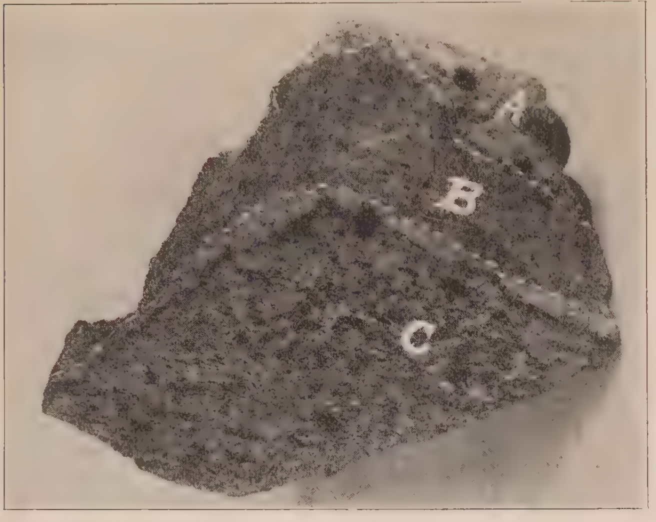
Good Condition of Gunite and Permanence of Bond with Concrete Disclosed in Demolished Bridge

A piece of the gunite protection taken from 28th Street bridge, Pittsburgh, Pa., in 1931, inspected under the direction of engineers of the city of Pittsburgh, is shown in the illustration. Another sample, cut from a point where it was 1 9/16 in. thick, which was tested by the engineer of tests for Allegheny County, disclosed the remarkable compressive strength of 16,700 lb. per sq. in.

Twenty-eighth Street bridge was built over the Pennsylvania Railroad tracks in 1880. In 1908 the approach spans were floored with a concrete slab, and the lower portions of the beams and girders were incased in concrete.

Gunite Applied in 1919

In 1919 a contract was let to protect with gunite the underside of the concrete, where it had badly deteriorated due to locomotive blast and gases. In 1931 the old bridge was entirely replaced, and in the demolition an exceptional opportunity was presented for examining the gunite and the concrete which it was intended to protect.



Sample of gunite shows bond with concrete

Slabs were cut out of the concrete and carefully lowered and stored. Then these slabs were broken up with pneumatic hammers, and an effort was made to split the gunite away from the concrete. This was unsuccessful, for the bond was everywhere perfect.

The picture shows a typical piece broken from that portion of the slab where no anchor bolts or mesh were used, and where bond alone was depended on to keep the gunite in place.

Impermeable Surface Coat

In the picture, "A" is a part of the old concrete, "B" is gunite, and the bond between the concrete and the gunite is at the broken white line between "A" and "B." "C" is the exposed face of the gunite, which shows a somewhat lighter color, because it is the so-called "flash coat," about ¼ in. thick, which is the final application. This is the surface which had been directly exposed to the locomotive blast for a period of 12 years. The line of bond between the body of the gunite and the gunite flash coat is shown by the broken white line between "B" and "C." An illustration of the impermeability of the gunite flash coat was given by the fact that the No. 14 gauge black tie wire, which had been used for holding the shooting strips in place, and which was later covered by the ¼-in. flash coat, were found to be still black in color, and with no loss of sectional area.

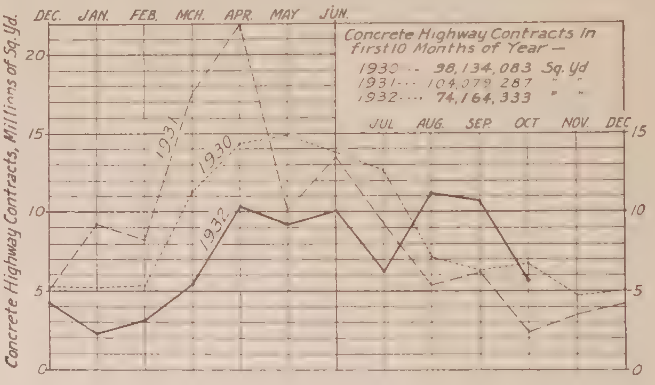
Deterioration Was Stopped

No place was found where the gunite had separated from the concrete. There was no evidence that the deterioration of the concrete had proceeded after the application of the gunite protective coat. The original gunite surface left by the cement-gun in 1919 was unaltered.

October Concrete Road Awards Held at Good Volume

Contracts in Tenth Month Are Twice the Yardage Awarded in October, 1931

October contracts awarded for concrete road construcion amounted to more than twice the yardage awarded in October, 1931. According to figures compiled by the Portland Cement Association, the total for October of this year was 5,667,115 sq. yd., while in the corresponding month of 1931 the contracts awarded totaled only 2,482,405 sq. yd.



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For the first 10 months of 1932 the contracts awarded for concrete roads were 71.2 per cent of the yardage awarded in the first 10 months of 1931. The comparison shows a decided improvement in the second half of this year, for during the first half of 1932 the yardage awarded was just half the yardage in the corresponding period of 1931.

State Highway Officials Meet

Members of the American Association of State Highway Officials met in annual convention at Washington, D. C., November 14 to 19.

National Slag Office

The National Slag Association announces the removal of its office to 1449 Leader Building, at Cleveland, Ohio. H. J. Love is manager.

Control of Ready-Mixed Concrete at Plant of Moderate Size

Concrete Technologist Discusses Article by D. V. Terrell in October Issue—Reply by Author Shows Method Sufficiently Accurate for Practical Purposes

An interesting discussion of D. V. Terrell's article on "Simplified Control of Ready-Mixed Concrete," published in the October (1932) issue of CONCRETE, has been received from T. C. Powers, associate engineer for the Portland Cement Association, who has had extensive experience in the control of concrete work on large construction projects, notably on Bull Run dam, built by the city of Portland, Oregon.

Operators of plants producing ready-mixed concrete, and concrete technologists engaged in this field of concrete production, will find in this discussion, as well as in Terrell's reply, a valuable contribution to this subject. Prof. Terrell reiterates his belief that the control methods given in his October article are sufficiently accurate for the plant of average size, where the annual production is such as to permit only a limited expenditure for technical service. The methods given by him, as he explains, have been employed with notable success in the operation of a ready-mixed concrete plant at Lexington, Kentucky. The discussions follow:

DISCUSSION BY T. C. POWERS

Professor Terrell's article appearing in the October, 1932, issue of CONCRETE, was of much interest to me, as it proposes a method of concrete control similar to the one which I described in *Engineering News-Record* for September 3, 1931.

I would like to point out that Professor Terrell's rule given at the bottom of the second column on page 9 is correct only when the moisture content of the aggregate at the time the rule is applied is the same as that assumed when figuring the quantities to use. Changes in the water requirement of a given weighed batch are most frequently due to changes in the moisture content of the materials. Under such conditions to add or subtract 23 lb. of damp aggregate for each gallon of water added or withheld is incorrect. This factor does not take into account that when weighing the aggregate each change in moisture content is accompanied by a corresponding change in the weight of the aggregate itself. In other words, at a constant gross weight an increase in the moisture content of the aggregate brings about an increase in the amount of water weighed in as aggregate. Perhaps an example will make this clear.

In Professor Terrell's article he figures a mix which requires 1,222 lb. of surface-dry sand. On the basis of 3 per cent moisture in the fine aggregate the gross weight of damp sand was 1,260 lb. With due allowances for the moisture in the materials, the quantity of water to add was found to be 35.91 gal. per batch. Suppose that in making the first trial batch the weight of sand computed by Professor Terrell (1,260 lb.) was used. If all conditions were such as those assumed in making the computation, the batch would then require 35.91 gal. to be added. Let us assume, however, that the actual water content of the sand was 6 per cent instead of 3 per cent. Thus, if the mixer operator weighed in 1,260 lb. of damp sand, instead of getting 1,222 lb. of surface-dry sand he would get 0.94 × 1,260 = 1,185 lb. of sand. At the same time he weighs in 1,260 — 1,185 = 75 lb., or 9 gal. of water. The total water required for the batch in Professor Terrell's example should be 41.54 gal. Subtracting the 9 gal., which was weighed in with the sand and the 1:1 gal., weighed in with the coarse aggregate (we are here assuming that the moisture in the coarse aggregate remains the same as that assumed in figuring the mix), there remains to be added to the mix 31.44 gal. of water.

As discussed in my article in *Engineering News-Record*, the actual amount which would be added to produce a given consistency would, in this case, be somewhat less than 31.44, due to the fact that the size of the batch would be somewhat smaller because of the reduction in the quantity of dry sand (1,185 instead of 1,222 lb.). Let us assume in this case that the quantity of water added under the conditions described will be not more than 31 gal. per batch. To apply Professor Terrell's rule: 35.91 minus 31 equals 4.91 gal. of water withheld. Then, 4.91 times 9 equals 44 lb. of sand to be added, and 4.91 × 14 = 68 lb. of coarse aggregate to be added, although in this case there was actually no call for a change in the quantity of coarse aggregate. Thus, the final weight of the batch, corrected according to Professor Terrell's rule, would be 1,300 lb. of damp sand and 1,906 lb. of damp coarse aggregate. This gives a net surface-dry weight of 1,225 and 1,900 lb. of fine aggregate and coarse aggregate respectively. In this case the sand is corrected to almost exactly the correct amount, but the coarse aggregate is increased to 67 lb. more than there should be.

Since in this case it was known that the moisture change took place in the sand only, it would be proper to apply the rule to the sand only; thus 4.91 × 23 = 113 lb. to be added to the weight of the sand. This would give a gross weight of 1,373 which, at 6 per cent moisture, gives the net weight of surface-dry sand to be 1,290 lb., or 68 lb. of sand too much.

The rule derived by the writer, described in the article previously mentioned, would, under the conditions just described, call for increasing the weight of the sand 8 lb. for every gallon of water withheld, in which case 4.91 × 8 = 39 lb. of sand is to be added. This would give the weight of the damp sand as 1,299 lb., which, at 6 per cent moisture, gives 1,221 lb. of surface-dry sand, virtually the correct quantity.

As pointed out in my article, it is not believed that correction factors based upon the water requirements of the mix can be successfully applied when the aggregate gradation is subject to wide or frequent variation. If, however, a situation could be found where the moisture content was always constant and the variations in water requirement were due entirely to changes in gradation of the materials, then the factors given by Professor Terrell would give accurate results.

T. C. Powers
Chicago, Illinois, *Associate Engineer,*
October 8, 1932 *Portland Cement Association*

DISCUSSION BY PROF. TERRELL

It is true as contended by Mr. Powers that my rules number four and six, which relate to the number of pounds of aggregate to add or leave out according as the water is withheld or added to the amount of water found by experiment and calculation to give the desired consistency, are not mathematically correct, so long as all of the correction is due to the moisture in the aggregate. If the correction is due to any other cause then the rules as stated are correct.

Under the most unfavorable conditions—that is, increase of the moisture content of the sand up to 6 per cent—with no increase of the moisture in the coarse aggregate, and assuming that the water calculated would give the exact consistency as desired, the final calculated values would be as follows:

(1) Water-cement ratio, strength and consistency remain constant. These are the most essential points of the control.
(2) The ratio of the fine to the coarse aggregate would change from 40-60 per cent to 39.2-60.8 per cent. It is not believed that so small a change would make any material difference in the workability or consistency.
(3) The theoretical volume would increase 1.5 per cent, or 0.4 cu. ft. per cu. yd. This is not a bad feature, since most of the complaints are on short measurement.
(4) The increase in volume would be reduced as the actual moisture content approaches the values used in the calculation.

Should any part of the water correction be due to causes other than increased moisture in the aggregate, then the actual volume would come closer to the theoretical volume.

It is not expected that wide changes will take place in the aggregate, and in general the volume should check inside of 1 per cent.

It was not intended to formulate a mathematically correct system of control, but to set up a control that a small operator could use with very little expense for technical service. The system has been in use at a local plant for the past year with excellent results.

D. V. Terrell
Lexington, Ky., *Prof. of Civil Engineering,*
October 22, 1932 *University of Kentucky*

Agricultural Engineers Discuss Silos and Housing

The structures division of the American Society of Agricultural Engineers is holding a 2-day session on November 28 and 29, at the Stevens Hotel, Chicago, as this issue of Concrete goes to press.

Several papers presented before the meeting are of special interest to the concrete products industry. These include a symposium on "Preservative Treatments for Masonry Silo Walls," with separate discussions by F. C. Fenton, agricultural engineer, Kansas State College; G. F. Steigerwalt, agricultural engineer, Portland Cement Association; and S. A. Witzel, agricultural engineer, University of Wisconsin.

Other papers include a discussion of the design of milk houses, by J. B. Kelley, agricultural engineer, University of Kentucky, and a treatment of the subject of industrial decentralization and rural housing problems, by Harry R. O'Brien, agricultural writer.

The secretary of the American Society of Agricultural Engineers is Raymond Olney, St. Joseph, Mich.

Manual of Modernizing Campaigns Prepared by Government

A 41-page mimeograph entitled "Tentative Operating Manual for Conducting a Local Modernizing Campaign" has been issued by the U. S. Department of Commerce, Washington, D. C.

The manual, which was prepared by the Committee on Reconditioning, Remodeling and Modernizing, under the chairmanship of Frederick M. Feiker, is intended to assist cities and towns in the stimulation of business and employment through improvements and repairs, and through the general promotion of community clean-up and beautification.

Copies of this mimeograph may be obtained on request, from the Department of Commerce.

Coming Conventions

December 1-2—Highway Research Board, twelfth annual meeting, National Academy of Sciences Building, Washington, D. C.

January 16-18—National Crushed Stone Association, sixteenth annual convention. Book-Cadillac Hotel, Detroit, Mich.

January 16-20—American Road Builders Association, annual convention and road show. Statler and Fort Shelby hotels, and Municipal airport.

January 16-23—Highway and Building Congress. First annual meeting. Detroit, Mich.

January 17-18—National Sand and Gravel Association, seventeenth annual convention. Book-Cadillac Hotel, Detroit, Mich.

January 18—National Ready-Mixed Concrete Association, third annual convention. Book-Cadillac Hotel, Detroit, Mich.

February 21-24—American Concrete Institute, twenty-ninth annual convention. Palmer House, Chicago, Ill.

June 26-30—American Society for Testing Materials, annual meeting. Stevens Hotel, Chicago, Ill.

HOW TO DO IT

✦ Questions and Answers ✦
Consultation and Comment

A department devoted to the solution of problems encountered in concrete work. Readers are welcome to add to or improve upon the suggestions printed and to submit their views for possible publication.

Comparative Maintenance Costs on Pavement Types

Please furnish us with recent figures showing a comparison of maintenance costs on reinforced concrete and sheet asphalt street pavements.—C. H. A., Luzerne, Pa.

Figures of the kind you request have been compiled by no less than twelve state highway departments, and these figures have been assembled by the Portland Cement Association in a mimeograph entitled, "State Highway Maintenance Costs."

Concerning city street pavements, the ratio of maintenance expenditures should be approximately the same as for state highways.

An accurate long-time record of maintenance costs on reinforced concrete street pavements has been kept by the city engineering department of Sheboygan, Wis., under the direction of Arthur L. Boley, city engineer. The record covers the period from 1911 to the present date. During this 22-year period that city has placed about 1,200,000 sq. yd. of reinforced concrete pavement, equivalent to 68 miles of streets 30 ft. wide.

A report prepared by Mr. Boley two years ago indicated that total maintenance expenditures during the 20 years covered by that report had averaged less than one-eighth of one cent per square yard per year. That means an annual maintenance of less than $1,500 on 68 miles of 30-ft. streets.

Reinforced Concrete Poles

Can you refer us to anything in the nature of accepted standard specifications for reinforced concrete telephone poles and similar products?—D. W. A., Chicago, Ill.

The Canadian Engineering Standards Association, 79 Sussex St., Ottawa, Canada, publishes such a specification under the serial designation and title of C14-1924, Standard Specification for Reinforced Concrete Poles. Copies may be obtained from the C. E. S. A. at 25 cents each.

Volcanic Rock as an Admixture

I understand there is an admixture, known as "trass," which is produced in Germany and is said to improve the workability of concrete. Can you tell me something about this material, and whether it is commercially available in this country?—C. L. W., Detroit, Mich.

The admixture known as "trass" is a light-colored volcanic tufa found on the lower Rhine. It is ground fine for use as a concrete admixture, and in some cases it is ground in with portland cement and sold, of course, as an ingredient of the cement.

The theory is that this finely ground volcanic rock combines chemically with the free lime that is sometimes liberated during the hardening of concrete.

Trass, as such, is probably not commercially available in this country; but some volcanic rock admixtures are produced here under other trade names.

Cement Plaster and Stucco

Can cement, sand and hair, with no lime or gypsum in the mix, be used successfully in interior plaster work?

Do you recommend a mixture of 1 part of cement to 2 parts of sand?

Could this mixture be used successfully when applied as exterior stucco work on lath?—S. A. J., Sacramento, Calif.

Hair or fiber to the amount of 1/5 to 1/3 of a bushel per sack of cement is sometimes used in the scratch coat on metal lath or wire lath, for interior cement plaster work. While the addition of a plasticizer such as lime is not absolutely necessary, plasterers usually prefer to add some such material to "fatten" the mortar. The addition of 10 lb. of hydrated lime to the sack of cement has been found, by experience, to provide the necessary "fattening" qualities. Some special commercial "fatteners" are used in quantities not exceeding 2 or 3 lb. to the sack of cement.

A mixture of 1:2 would be entirely too rich in cement. It might cause the formation of shrinkage checks, because of the excessive quantity of cement. The proportions commonly used are 1 part of cement to 3 parts of sand.

The mixture just described is suitable for exterior stucco work as well as interior plaster work, but in each case the lath used must be metal or wire lath. Cement plaster or stucco should never be placed on wood lath.

Doubtless you are familiar with the fact that cement plaster or cement stucco may be placed directly on masonry or concrete, without the use of lath. Cement plaster is also frequently applied to the outside of masonry or concrete foundation walls, to a thickness of about ½ in., for the purpose of making the wall watertight.

An excellent booklet on cement plaster and stucco is the "Plasterer's Manual," published by the Portland Cement Association.

Adhesive Strength of Mortars

I am making a report on the adhesive strength of both cement and lime mortars to bricks. Where can I get references to test results and test methods covering this subject?—M. A. R., Ithaca, N. Y.

If you will write to D. E. Parsons, chief, masonry construction section, U. S. Bureau of Standards, Washington, D. C., you can doubtless obtain extensive information on this subject. Mr. Parsons has investigated all phases of masonry and masonry mortars, and much of the information he has developed has appeared in published form.

New Books and Pamphlets

Temperature and Humidity

HANDBOOK OF INDUSTRIAL TEMPERATURE AND HUMIDITY MEASUREMENT AND CONTROL. By M. F. Behar. Published by the Instruments Publishing Co., Pittsburgh, Pa., 1932. Cloth, 320 pages, 6 by 9¼ in., with 278 illustrations. Price $4.00.

Two separately titled books are here combined into one volume, namely, "Temperature Measurement and Control" and "Humidity Measurement and Control." These constitute, respectively, Part Two and Part Three of the Manual of Instrumentation which the author undertook several years ago with the purpose of laying the foundation of a modernized form of industrial engineering.

Major subjects covered in this volume include industrial thermometry, pyrometry, temperature control, and humidity measurement and control. Much of the material finds application in the operation and control of temperature-control and humidity-control rooms in concrete laboratories, and with steam curing chambers of concrete products plants.

Weathering of Masonry Materials

SYMPOSIUM ON WEATHERING CHARACTERISTICS OF MASONRY MATERIALS. Reprinted by the American Society for Testing Materials from the 1931 Proceedings of the A. S. T. M. Paper cover, 128 pages, 6 by 9 in.

This reprint includes the discussions as well as the original papers on the effect of weathering on various masonry materials. Monolithic concrete, natural stone, concrete masonry units and structural clay products are included in the investigations reported. Weathering test procedures for the various masonry materials also are given.

Movement of Bridge Piers

MOVEMENT OF PIERS DURING CONSTRUCTION OF MULTIPLE-SPAN REINFORCED CONCRETE ARCH BRIDGES is the title of Bulletin No. 234, University of Illinois Engineering Experiment Station, Urbana, Ill.

This bulletin, prepared by Wilbur M. Wilson, research professor of structural engineering, University of Illinois, reports the results of observations conducted by the author during the construction of the Fox River bridge at Yorkville, Ill., the Washington Street bridge at Rockton, Ill., and the Oliver Avenue and Kentucky Avenue bridges at Indianapolis, Ind.

Proportioning of Concrete

DOSAGEM DOS CONCRETOS (Proportioning of Concretes), by Ary F. Torres, is the title of a well prepared 59-page bulletin published in the Portuguese language as Bulletin No. 1 of the Laboratorio de Ensaio de Materiaes, Escola Polytechnica de Sao Paulo, of Sao Paulo, Brazil. The author is director of the laboratory.

The bulletin consists of three parts, the first of which deals with the strength of concrete, the second is a study of consistency, and the third describes methods of scientific proportioning of concrete.

‹ ORGANIZATIONS ›

AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS; W. C. Markham, Executive Secretary, 1222-24 National Press Building, Washington, D. C.

AMERICAN CONCRETE INSTITUTE; Harvey Whipple, Secretary, 641 New Center Building, Detroit, Mich. Twenty-ninth annual convention, Feb. 21-24, Palmer House, Chicago, Ill.

AMERICAN CONCRETE PIPE ASSOCIATION; M. W. Loving, Secretary, 33 West Grand Ave., Chicago.

AMERICAN ROAD BUILDERS' ASSOCIATION; Chas. Upham, Engineer-Director, National Press Building, Washington, D. C. Annual convention and road show, Jan. 16-20. Statler and Fort Shelby Hotels, and Detroit Municipal Airport.

AMERICAN SOCIETY OF CIVIL ENGINEERS; Geo. T. Seabury, Secretary, 33 West Thirty-ninth St., New York City.

AMERICAN SOCIETY FOR TESTING MATERIALS; C. L. Warwick, Secretary-Treasurer, 1315 Spruce St., Philadelphia, Pa. Annual meeting, June 26-30, Stevens Hotel, Chicago, Ill.

ASSOCIATED GENERAL CONTRACTORS OF AMERICA; E. J. Harding, Managing Director, 222 Munsey Bldg., Washington, D. C.

BUILDING OFFICIALS CONFERENCE OF AMERICA; Col. John W. Oehmann, Secretary, 1253 Lawrence St., N. E., Washington, D. C.

CAST STONE INSTITUTE; L. A. Falco, Secretary, Chapel St. and Blatchley Ave., New Haven, Conn.

CEMENT INSTITUTE; Luther G. McConnell, General Manager, 11 East 44th St., New York City.

CONCRETE MASONRY ASSOCIATION; Jack Franklin, Secretary, 7071 Plankinton Bldg., Milwaukee, Wis.

CONCRETE REINFORCING STEEL INSTITUTE; M. A. Beeman, Secretary, 333 North Michigan Ave., Chicago.

ENGINEERING INSTITUTE OF CANADA; 2050 Mansfield St., Montreal, Quebec.

HIGHWAY RESEARCH BOARD; Roy W. Crum, Director, 2101 Constitution Ave., Washington, D. C. Twelfth annual meeting, Dec. 1-2. National Academy of Sciences, Washington.

JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE; F. R. McMillan, Secretary, 33 West Grand Ave., Chicago.

NATIONAL BOARD OF FIRE UNDERWRITERS; W. E. Mallalieu, General Manager, 85 John St., New York City.

NATIONAL CONCRETE BURIAL VAULT ASSOCIATION; J. H. Stuart, Secretary-Treasurer, Bremen, Ohio.

NATIONAL CRUSHED STONE ASSOCIATION; J. R. Boyd, Secretary, 1735 14th Street, N. W., Washington, D. C. Sixteenth annual convention, Jan. 16-18. Book-Cadillac Hotel, Detroit, Mich.

NATIONAL ENGINEERING INSPECTION ASSOCIATION; B. H. Witherspoon, Secretary, P. O. Box 1115, Pittsburgh, Pa.

NATIONAL FIRE PROTECTION ASSOCIATION; Franklin H. Wentworth, Secretary, 40 Central St., Boston, Mass.

NATIONAL LIME ASSOCIATION; Norman G. Hough, Secretary and Manager, 927 Fifteenth St., N. W., Washington, D. C.

NATIONAL READY-MIXED CONCRETE ASSOCIATION; V. P. Ahearn, Secretary, 545 Munsey Building, Washington, D. C. Third annual convention, Jan. 18. Book-Cadillac Hotel, Detroit, Mich.

NATIONAL SAND AND GRAVEL ASSOCIATION; V. P. Ahearn, Executive Secretary, 545 Munsey Bldg., Washington, D. C. Seventeenth annual convention, Jan. 17-18. Book-Cadillac Hotel, Detroit, Mich.

NATIONAL SLAG ASSOCIATION; H. J. Love, Secretary-Treasurer, 1449 Leader Bldg., Cleveland, Ohio.

NATIONAL TERRAZZO AND MOSAIC ASSOCIATION; U. F. Durner, Secretary, 815 West St. Paul Ave., Milwaukee, Wis.

NORTHWEST CONCRETE PRODUCTS ASSOCIATION; W. P. Hews, Secretary-Treasurer, Yakima, Wash.

PORTLAND CEMENT ASSOCIATION; Edward J. Mehren, President; William M. Kinney, General Manager, 33 West Grand Ave., Chicago.

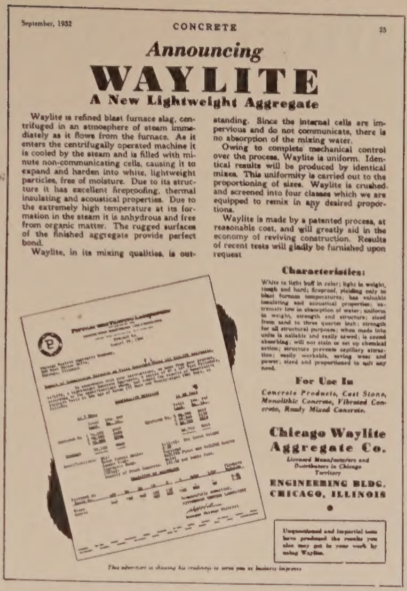
RAIL STEEL BAR ASSOCIATION; H. P. Bigler, Engineering Secretary; Builders' Bldg., 228 N. La Salle St., Chicago, Ill.

WIRE REINFORCEMENT INSTITUTE; R. D. Bradbury, Director, National Press Bldg., Washington, D. C.

WISCONSIN CONCRETE PRODUCTS ASSOCIATION; Jack Franklin, Secretary-Treasurer, 425 East Water St., Milwaukee, Wis.

Immediate Acceptance

1–Announced



September, 1932 CONCRETE 25

Announcing

WAYLITE

A New Lightweight Aggregate

Waylite is refined blast furnace slag, centrifuged in an atmosphere of steam immediately as it flows from the furnace. As it enters the centrifugally operated machine it is cooled by the steam and is filled with minute non-communicating cells, causing it to expand and harden into white, lightweight particles, free of moisture. Due to its structure it has excellent fireproofing, thermal insulating and acoustical properties. Due to the extremely high temperature at its formation in the steam it is anhydrous and free from organic matter. The rugged surfaces of the finished aggregate provide perfect bond.

Waylite, in its mixing qualities, is outstanding. Since the internal cells are impervious and do not communicate, there is no absorption of the mixing water.

Owing to complete mechanical control over the process, Waylite is uniform. Identical results will be produced by identical mixes. This uniformity is carried out to the proportioning of sizes. Waylite is crushed and screened into four classes which we are equipped to remix in any desired proportions.

Waylite is made by a patented process, at reasonable cost, and will greatly aid in the economy of reviving construction. Results of recent tests will gladly be furnished upon request.

Characteristics:

White to light buff in color; light in weight, tough and hard; fireproof, yielding only to blast furnace temperatures; has valuable insulating and acoustical properties; extremely low in absorption of water; uniform in weight, strength and structure; sized from sand to three quarter inch; strength for all structural purposes; when made into units is nailable and easily sawed; is sound absorbing; will not stain or set up chemical action; structure prevents capillary attraction; easily workable, saving wear and power; sized and proportioned to suit any need.

For Use In

Concrete Products, Cast Stone, Monolithic Concrete, Vibrated Concrete, Ready Mixed Concrete.

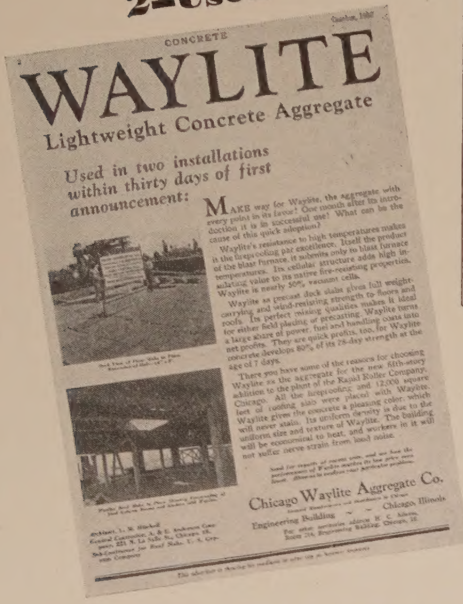
Chicago Waylite Aggregate Co.

Licensed Manufacturers and Distributors in Chicago Territory

**ENGINEERING BLDG.
CHICAGO, ILLINOIS**

Unquestioned and impartial tests have produced the results you also may get in your work by using Waylite.

2–Used



CONCRETE

WAYLITE

Lightweight Concrete Aggregate

Used in two installations within thirty days of first announcement:

MAKE way for Waylite, the aggregate with every point in its favor! One month after its introduction it is in successful use! What can be the cause of this quick adoption?

Waylite's resistance to high temperatures makes it the fireproofing par excellence. Itself the product of the blast furnace, it submits only to blast furnace temperatures. Its cellular structure adds high insulating value to its native fire-resisting properties. Waylite is nearly 50% vacuum cells.

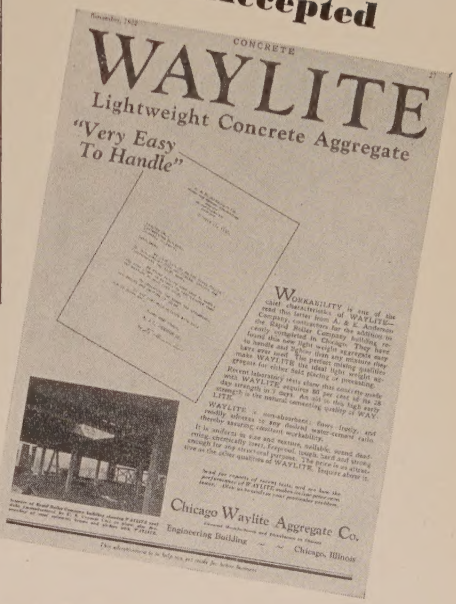
Waylite as precast deck slabs gives full weight-carrying and wind-resisting strength to floors and roofs. Its perfect mixing qualities makes it ideal for either field placing or precasting. Waylite turns a large share of power, fuel and handling costs into net profits. They are quick profits, too, for Waylite concrete develops 80% of its 28-day strength at the age of 7 days.

There you have some of the reasons for choosing Waylite as the aggregate for the new fifth-story addition to the plant of the Rapid Roller Company, Chicago. All the fireproofing and 12,000 square feet of roofing slab were placed with Waylite. Waylite gives the concrete a pleasing color which will never stain. Its uniform density is due to the uniform size and texture of Waylite. The building will be economical to heat, and workers in it will not suffer nerve strain from loud noise.

Chicago Waylite Aggregate Co.

Engineering Building ~ ~ Chicago, Illinois

3–Accepted



CONCRETE

WAYLITE

Lightweight Concrete Aggregate

"Very Easy To Handle"

WORKABILITY is one of the chief characteristics of WAYLITE—read this letter from A. & E. Anderson Company, contractors for the addition to the Rapid Roller Company building recently completed in Chicago. They have found this new light weight aggregate easy to handle and lighter than any mixture they have ever used. The perfect mixing qualities make WAYLITE the ideal light weight aggregate for either field placing or precasting.

Recent laboratory tests show that concrete made with WAYLITE acquires 80 per cent of its 28 day strength in 7 days. An aid to this high early strength is the natural cementing quality of WAYLITE.

WAYLITE is non-absorbent; flows freely, and readily adheres to any desired water-cement ratio thereby assuring constant workability.

It is uniform in size and texture, nailable, sound deadening, chemically inert, fireproof, tough, hard and strong enough for any structural purpose. The price is as attractive as the other qualities of WAYLITE. Inquire about it.

Chicago Waylite Aggregate Co.

Engineering Building ~ ~ Chicago, Illinois

WAYLITE

LIGHTWEIGHT CONCRETE AGGREGATE

Sixty days after the first announcement WAYLITE is the talk of the industry.

New uses, new products and new evidence of WAYLITE'S superior qualities are being unfolded each day. Every quality you may want in an aggregate is to be found in WAYLITE.

Contractors, engineers, architects, concrete product manufacturers are being won over to the new lightweight aggregate because of these qualities:

Workable
Strength
Insulation
Non-absorbent
Nailable
Sawable
Uniform
Non-Stain

WAYLITE concrete made of WAYLITE aggregates fulfills all structural requirements as to strength and absorption.

Send for report of recent tests, and see how the performance of WAYLITE makes its low price even lower. Allow us to analyze your particular problem.

CHICAGO WAYLITE AGGREGATE CO.

*Licensed Manufacturers and Distributors
in Chicago Territory*

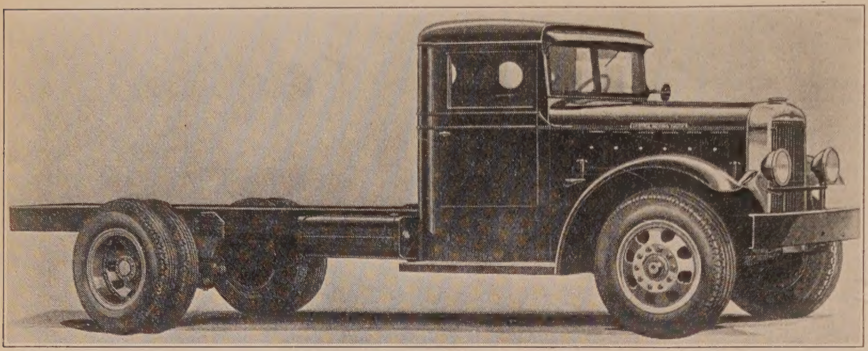
Engineering Building **Chicago, Illinois**

This advertiser is showing his readiness to serve you as business improves

New Equipment and Materials

Super Heavy-Duty Trucks by General Motors

Extension of its line into the super-heavy duty field is announced by the General Motors Truck Co. through Joseph P. Little, vice president directing sales. General Motors Truck is introducing two new models, the T-110 and the T-130, with straight ratings of 40,000 and 50,000 lb. respectively. The gross weight ratings provide a capacity range of from 8 to 12 tons payload on the T-110 and from 12 to 15 tons payload on the T-130 depending upon body weight and tire capacity.



The T-110 is a four-wheel unit equipped with a full-floating double-reduction type rear axle. The T-130 is a six-wheel unit having dual rear axles of the heavy-duty, worm-drive, full-floating tandem type, with inter-axle differential. Equal division of load between the four sets of driving wheels is assured by equalizing beams and balanced spring suspension.

Both of the new models are powered with the G.M.T. 616 six-cylinder valve-in-head engine having a 4⅞-in. bore by 5½-in. stroke and 616-cu. in. displacement. The S.A.E. rating is 57.04 hp. This engine develops 149 h.p. at the governed speed of 2,100 r.p.m. while maximum torque is 450 lb. at 1,000 r.p.m. The G.M.T. 468 or 525 valve-in-head six-cylinder engines are optional at price deductions on either truck, and the G.M.T. 707, developing 173 at its governed speed of 2,100 r.p.m., is available at extra cost.

These engines embody such advancements as the exclusive "Zero Lash" automatic valve-adjusting mechanism, replaceable hardened semi-steel sleeves in each cylinder bore, G.M.R. type combustion chambers in two-piece interchangeable head, counterweighted seven-bearing crankshaft with harmonic balancer, stellite-faced exhaust valve seats and full pressure lubrication.

Lubrication is especially efficient. There is a two-stage oil pump, low-pressure and high-pressure, a cleanable type oil filter, and an oil cooler which keeps viscosity range of lubricant more nearly constant. There are no outside oil lines on any part of the engine.

Numerous options, adapting these trucks to special requirements in any sector of the heavy-duty field, are available on both the T-110 and the T-130.

Salient features of both models, aside from engine features, include a rugged large-capacity radiator of flat-tube construction, permitting freedom from breakage when frozen, entire assembly being spring-leaf mounted as a protection from shock; heavy-duty double-disc clutch of multiple-spring design, with ball thrust release bearing and telescopic mounting of hubs, allowing each disc to position itself independently; four-speed heavy-duty truck type main transmission with shafts carried on ball and roller bearings and all gears pack-hardened 5 per cent nickel-steel with wide faces assuring silent operation and long life. Two large S.A.E. power take-off openings.

Forty-gallon fuel tank, of heavy gauge Terne plate, lap seamed and soldered at all joints, and equipped with gauge is mounted conveniently on right side of frame. Two six-volt 111-ampere-hour storage batteries, in series for 12-volt system are mounted on left running board. Standard chassis equipment is particularly complete including, among other items, flat back cowl with two ventilators, oil gauge, speedometer, water temperature indicator, air gauge, ammeter, jack, spare wheel, high pressure grease-gun and full set of tools.

INDUSTRIAL LITERATURE

Testing Equipment Bulletins on Olsen Products

Recent publications issued by the *Tinius Olsen Testing Machine Co.*, Philadelphia, Pa., are *Bulletins* 8 and 9, supplementing *Catalogs C* and 50-A respectively.

The former covers a road surface rater and a concrete beam testing machine, drain tile and sewer pipe testing machine, and a master straight-edge.

The latter contains data on a pendulum dial load indicator lever weighing system and a recorder.

Newark Wire Cloth Folder on Sieves

The Newark Wire Cloth Co., Newark, N. J., manufacturers of wire cloth of all meshes, weaves, and metals, have issued a six-page folder which is devoted entirely to two of their products: their new End-Shak testing sieve shaker and their U. S. Standard and A. S. T. M. standard cornerless testing sieves.

The folder contains valuable descriptive matter, tables, etc., on Newark testing sieves and on the End-Shak machine which is not obtainable elsewhere in concentrated form. A copy will be sent upon request.

Corner-Turning Conveyor

The Stephens-Adamson Mfg. Co., Aurora, Ill., has acquired the United States right to manufacture and distribute the English *Redler* conveyor, which is claimed to convey horizontally, vertically, and up inclines, as well as around corners.

A 4-page descriptive folder has been issued to explain the novel principle upon which this new conveyor operates.

Manufacturers' News

Ferrocrete Appoints Bragger as Representative

The Ferrocrete Cement Co., Inc., New York City, has appointed *Ernest Y. Bragger* in charge of the sale of Snowcrete white portland cement, waterproofed white portland cements, colored portland cements and allied products.

Mr. Bragger has devoted the last 25 years to the promotion and sales of similar products.